State of Louisiana

Coastal Protection and Restoration Authority of Louisiana (CPRA)

2016 Operations, Maintenance, and Monitoring Report

for

West Belle Pass Headland Restoration (TE-23)

State Project Number TE-23
Priority Project List 2

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Lafourche Parish

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Operations, Maintenance, and Monitoring Report
for
West Belle Pass Headland Restoration
(TE-23)

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Preface

This report includes monitoring data collected through December 2015, and annual Maintenance Inspections through April 2016. The West Belle Pass Headland Restoration (TE-23) project is federally sponsored by the United States Army Corps of Engineers, New Orleans District (USACE-NOD) and locally sponsored by the Coastal Protection and Restoration Authority of Louisiana (CPRA) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III). TE-23 is listed on the 2^{nd} CWPPRA Priority Project List (PPL-02).

The 2016 report is the 2^{nd} in a series of OM&M reports since the end of project construction in July 1998 and is the final manuscript written for the TE-23 project. This Operations, Maintenance, and Monitoring Report as well as an earlier report (Curole and Huval 2005) in this series are posted on the Coastal Protection and Restoration Authority (CPRA) website at *http://cims.coastal.louisiana.gov/DocLibrary/DocumentSearch.aspx* and on the official CWPPRA website at http://www.lacoast.gov/new/Projects/Info.aspx?num=TE-23 .

I. Introduction

The West Belle Pass Headland Restoration (TE-23) project is a shoreline protection and saline marsh creation project located on the southwestern portion of the Caminada-Moreau Headland at the interface of the Belle Pass navigation channel and the Gulf of Mexico (Figures 1, 2, and 3). Additionally, the project is situated directly across the federally maintained Bayou Lafourche navigation channel from Port Fourchon in Lafourche Parish, Louisiana (Figures 2 and 3). The western portion of the headland is separated from the vastly larger eastern part via the Belle Pass Rock Jetties and forms its southern border with the Gulf of Mexico and its northern border with Timbalier Bay (Figures 2 and 3). The project area consists of 543 ha (1,341 acres) of saline marsh, scrub-shrub, beach/bar/flat, and open water habitats (Figure 3).

The formation of the Lafourche delta complex began approximately 3,500 years before present (Peyronnin 1962; Frazier 1967; Otvos 1969; Conaster 1971; Harper 1977). During this time, nutrient rich sediments were deposited along the banks of the Lafourche delta distributaries primarily through overbank flooding. This created a vast network of swamps, marshes, and ridges along its numerous subdeltas (Frazier 1967; Reed 1995). This delta lobe complex was the fifth deltaic sequence of the Mississippi River (Frazier 1967; Bird 2000) to form in the delta plain’s geosyncline (Frazier 1967; Penland and Ramsey 1990; Roberts et al. 1994; Bird 2000). Bayou Lafourche was one of the final subdeltas to form during the Lafourche delta period before the river switched its flow to the Plaquemines and Modern delta complexes. This subdelta was an active distributary of the Mississippi River from approximately 1800 to 100 years before present (Morgan and Larimore 1957; Peyronnin 1962; Frazier 1967). At the mouth of the Bayou Lafourche subdelta, a regressing network of accretionary sand ridges developed to form the Caminada-Moreau Headland (Figure 2). These ridges were geomorphodynamically formed by shaping delta front sheet sands through

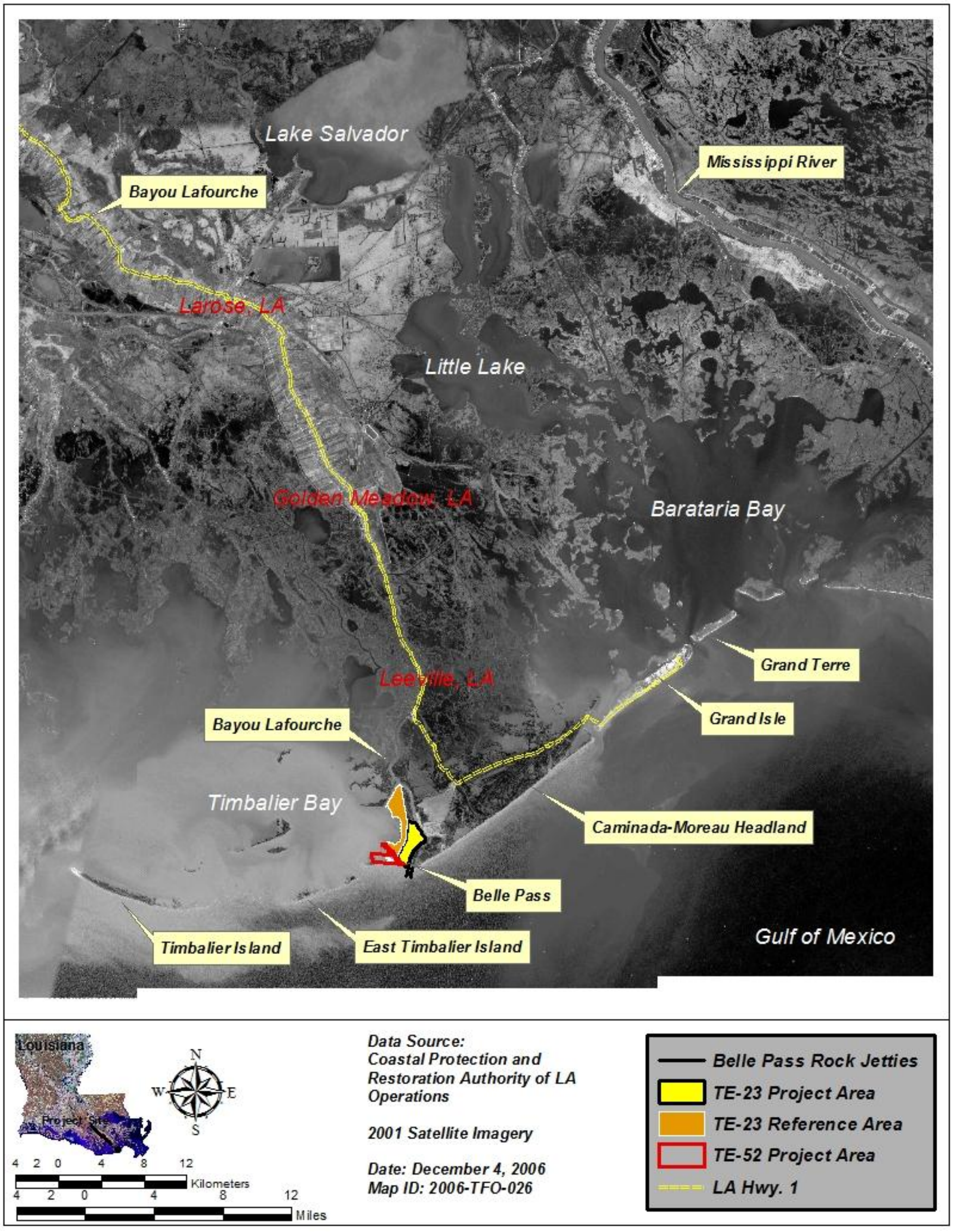

Figure 1. Location and vicinity of the West Belle Pass Headland Restoration (TE-23) project.

Figure 2. **Geomorphic and anthropogenic features of the Caminada-Moreau Headland.**

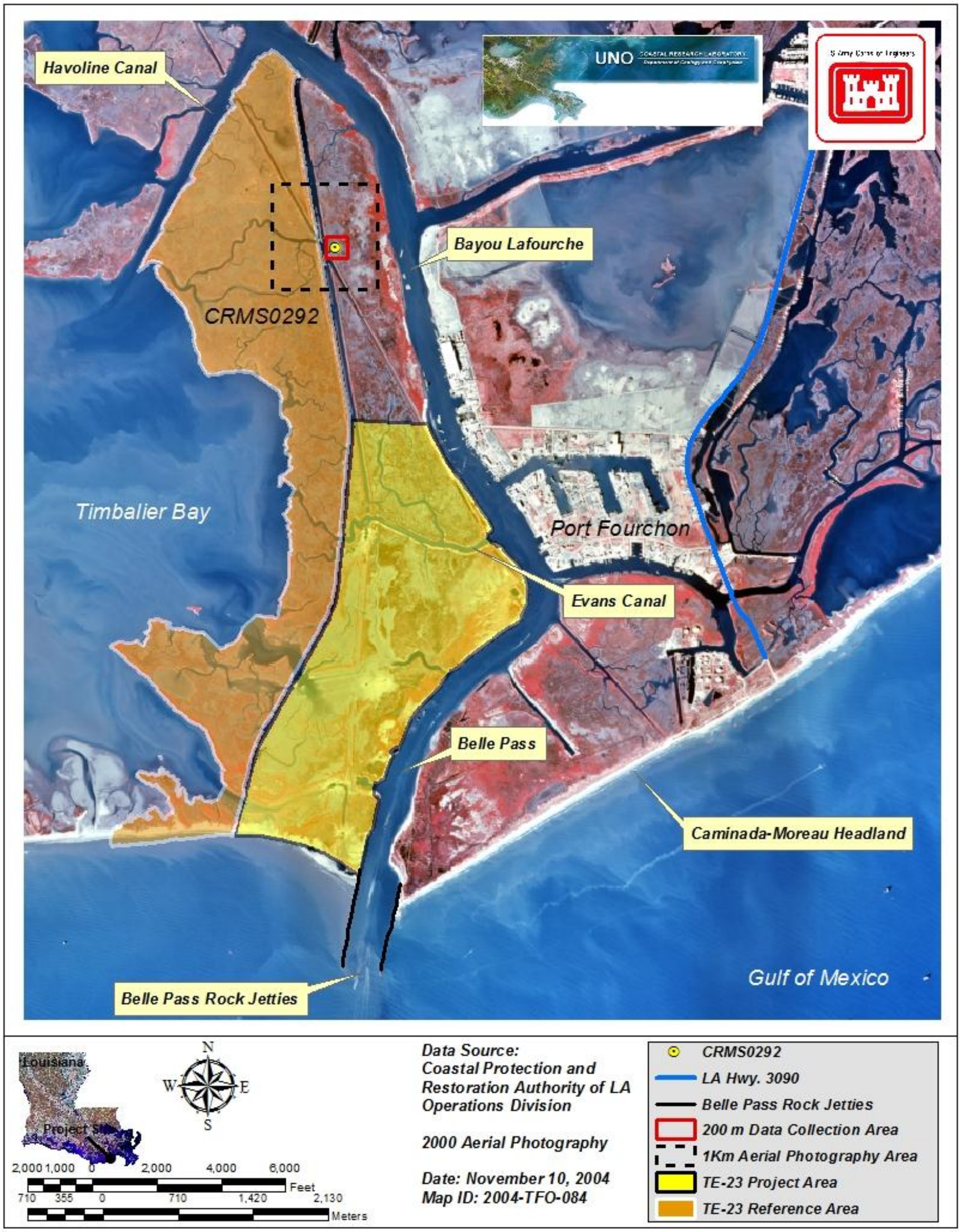

Figure 3. **Location of the West Belle Pass Headland Restoration (TE-23) project and reference areas.**

wind, wave, tidal, and longshore transport processes (Otvos 1969; Conaster 1971; Ritchie 1972; Bird 2000).

The soils in the project area are mostly composed of a Bellepass-Scatlake association. These organic and mineral soils are found in very poorly drained saline marshes. Scatlake muck and Felicity loamy fine sand soils are also found in the project area. The Scatlake muck soil is a very poorly drained mineral soil that is located along the Belle Pass and Bayou Lafourche shoreline while the Felicity loamy fine sand soil is established along the Gulf of Mexico beaches and consists of a somewhat poorly drained sandy soil (USDA 1984).

Marsh vegetation in the project area is dominated by *Spartina alterniflora* Loisel. (smooth cordgrass). *Avicennia germinans* (L.) L (black mangrove), *Spartina patens* (Ait.) Muhl. (marshhay cordgrass), *Salicornia virginica* L. (glasswort), *Solidago sempervirens* L. (seaside goldenrod), *Baccharis halimifolia* L. (eastern baccharis), *Iva frutescens* L. (bigleaf sumpweed), *Morella cerifera* (L.) Small (waxmyrtle), *Batis maritima* L. (saltwort), and *Distichlis spicata* (L.) Greene (seashore saltgrass) have also been found to inhabit the project area (USDA 1984). Sasser et al. (2014) classified the project area as salt marsh habitat.

In the years since the creation of the Lafourche delta, the sediment and freshwater supply to the Caminada-Moreau Headland has decreased considerably while the shoreline has noticeably transgressed. The Mississippi River gradually changed its course to form the Plaquemine and Modern delta lobes significantly reducing the sediment supply to the Caminada-Moreau Headland (Frazier 1967; Reed 1995). By 1850, the Bayou Lafourche subdelta was discharging only 15.0 % of the Mississippi River's flow (Reed 1995). In 1904, a dam was placed at the junction of the Mississippi River and Bayou Lafourche essentially eliminating the source of river sediments to the headland (Morgan and Larimore 1957; Peyronnin 1962; Frazier 1967; Dantin et al. 1978; Reed 1995). Therefore, Bayou Lafourche has become a sediment starved, relict distributary of the Mississippi River (Peyronnin 1962; Ritchie 1972; Harper 1977; Dantin et al. 1978; Penland and Ritchie 1979; Boyd and Penland 1981; Ritchie and Penland 1988a; Ritchie and Penland 1988b; Penland and Ramsey 1990; Reed 1995; Pilkey and Fraser 2003). This sediment deficit, the depth of the Holocene sediments in the delta plain's geosyncline (Frazier 1967; Otvos 1969; Conaster 1971; Penland and Ramsey 1990; Roberts et al. 1994; Bird 2000), and eustatic sea level rise (Scavia et al. 2002) have caused the subsidence rate along the Caminada-Moreau Headland to exceed 0.4 in/yr (1.0 cm/yr) (Coleman and Smith 1964; Swanson and Thurlow 1973; Penland and Ramsey 1990; Roberts et al. 1994). In addition, the placement of the Belle Pass Jetties (Figures 2 and 3) and the net longshore transport have impeded the movement of sediments to the project area. Jetties and groins have been found to obstruct sand transport along beaches causing erosion on the downdrift side of these structures (Conaster 1971; Komar 1998) and are likely contributors to alterations in sediment transport in the project area. Net longshore transport west of the rock jetties is in the western direction (Peyronnin 1962; Dantin et al. 1978; Ritchie and Penland 1988b; Stone and Zhang 2001; Thomson et al. 2009) (Figure 2). Longshore transport processes have caused extensive shoreface erosion along the West Belle Pass area shifting sediments to downdrift barrier islands and tidal passes (Peyronnin 1962;

Levin 1993; List et al. 1997; McBride and Byrnes 1997; Stone and Zhang 2001). The high frequency and intensity of tropical storm (Peyronnin 1962; Stone et al. 1997) and cold front (Boyd and Penland 1981; Ritiche and Penland 1998b; Dingler and Reiss 1990; Georgiou et al. 2005) events have been shown to induce erosion along the Caminada-Moreau Headland. Moreover, this area has been classified as a storm dominated coast (Harper 1977; Boyd and Penland 1981) consisting of ephemeral dunes shaped by storm events (Ritchie 1972; Harper 1977; Penland and Ritchie 1979; Ritchie and Penland 1988a; Ritchie and Penland 1988b). The sediment deficit, subsidence, longshore transport, and the high frequency of storm events have resulted in high shoreline erosion rates along the low profile Caminada-Moreau Headland (Morgan and Larimore 1957: Dantin et al. 1978; Williams et al. 1992). The shoreline change rate on western Caminada-Moreau Headland has been estimated to be -25 m/yr (-82 ft/yr) in the long-term (1887-2002) (Penland et al. 2005) and -11 m/yr (-36 ft/yr) in the short-term (1996-2008) (Thomson et al. 2009).

The geomorphology of the Caminada-Moreau Headland also has been strongly influenced through the frequent passage of tropical storms (Figure 4) and cold fronts. Numerous tropical storms (Peyronnin 1962; Stone et al. 1997) and cold fronts (Boyd and Penland 1981; Dingler and Reiss 1990; Ritiche and Penland 1998b; Georgiou et al. 2005) have elevated water levels high enough to cause partial or total overwash along the low profile Caminada-Moreau Headland. Hurricanes have caused severe overwash along or in the vicinity of the headland since 1856 (Peyronnin 1962; Stone et al. 1997). Specifically, Hurricane Betsy in 1965 (Conaster 1971), Hurricane Carmen in 1974 (Harper 1977), Hurricanes Juan, Danny, and Elena in 1985 (Ritchie and Penland 1988b), Hurricane Andrew in 1992 (Stone et al. 1993), Hurricanes Cindy, Katrina, and Rita in 2005 (Barras 2006), and Hurricane Isaac in 2012 (Devisse and Thomson 2013) have been documented as causing breaching, overwash, and shoreline retreat along the Caminada-Moreau Headland substantially altering the dune and washover environments (Figure 4). Hurricanes Isidore and Lili in 2002 (Curole et al. 2012), T. S. Matthew in 2004 (Roudrigue et al. 2011), Hurricanes Gustav and Ike in 2008 (Curole and Lee 2013), and T. S. Lee in 2011 (Brown 2011) have also been found to effect the geomorphology of barrier islands and wetlands in the vicinity of the headland and likely had an impact on the future TE-23 project area shorelines (Figure 4). As a result, hurricanes have been postulated as the major force driving morphodynamic change along the Caminada-Moreau Headland (Stone et al. 1997).

The construction of the Bayou Lafourche and Belle Pass Navigation Channel, the Belle Pass Rock Jetties, three pipeline canals, and two submerged pipelines (Figure 5) have altered the West Belle Pass Headland Restoration (TE-23) project area marshes. Belle Pass dredging and jetty construction began in 1940 by increasing the depth and width of the channel to unspecified dimensions and constructing parallel rock jetties 152 m (500 ft) in length and 61 m (200 ft) in width. The jetties were extended by 90 m (300 ft) in 1945 due to shoreline erosion. In 1958, the navigation channel was enlarged to a depth of -4 m (-12 ft) Mean Low Gulf (MLG) and a width of 30.5 m (100 ft). The channel was expanded to a 38 m (125 ft) bottom width and relocated to the west of the jetties in 1963 leaving only an eastern jetty (Dantin et al. 1978). A western jetty was installed in 1974, and Belle Pass was dredged to a -6

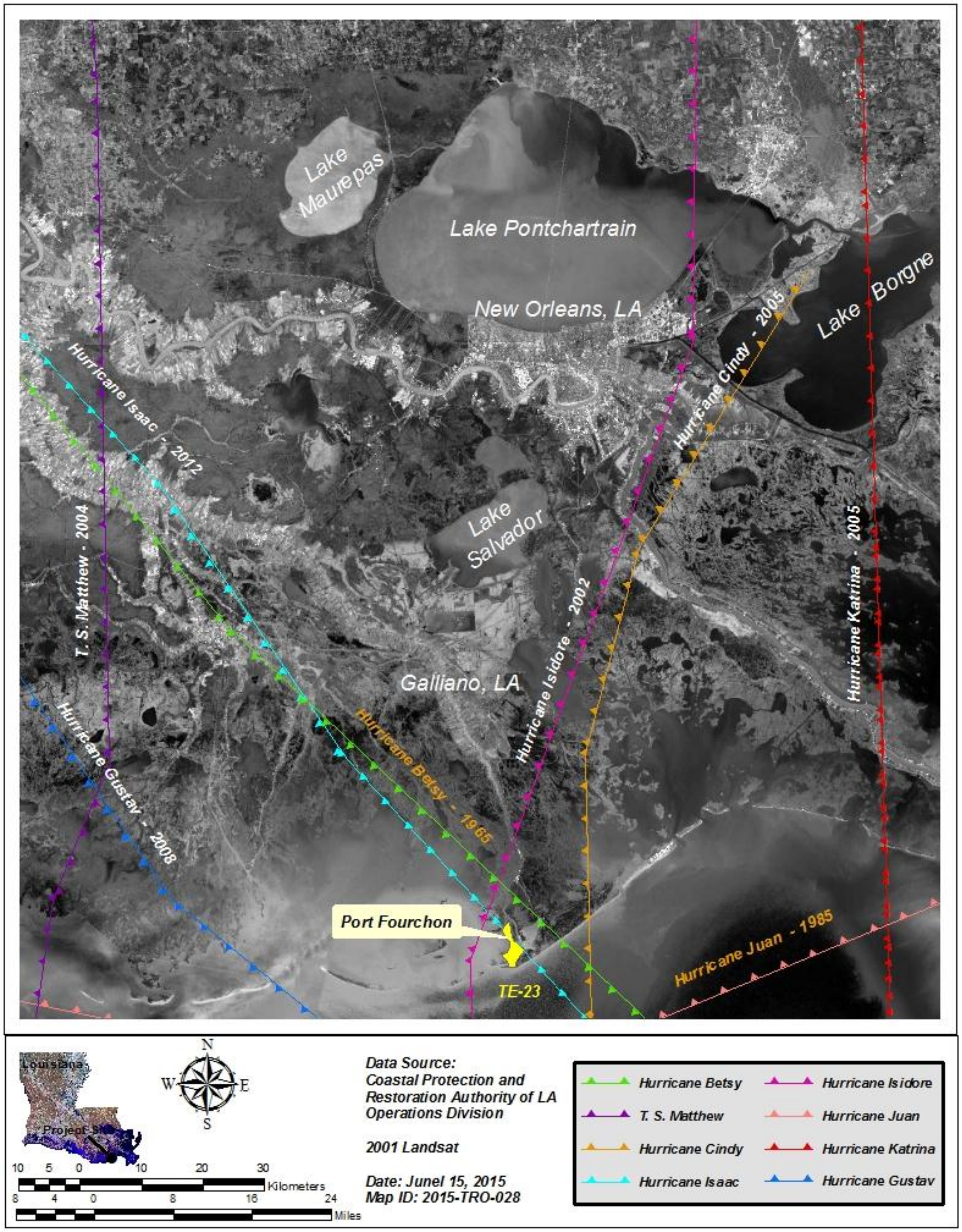

Figure 4. Pre-construction (1965, 1985) and post-construction (2002, 2004, 2005, 2008, and 2012) tropical storms impacting the West Belle Pass Headland Restoration (TE-23) project area shoreline. Hurricanes Carmen (1974), Danny and Elena (1985), Andrew (1992), Lili (2002), Ivan (2004), Rita (2005), Ike (2008), and T. S. Lee (2011) are not shown because the eye wall of these storms traversed outside the extent of this map.

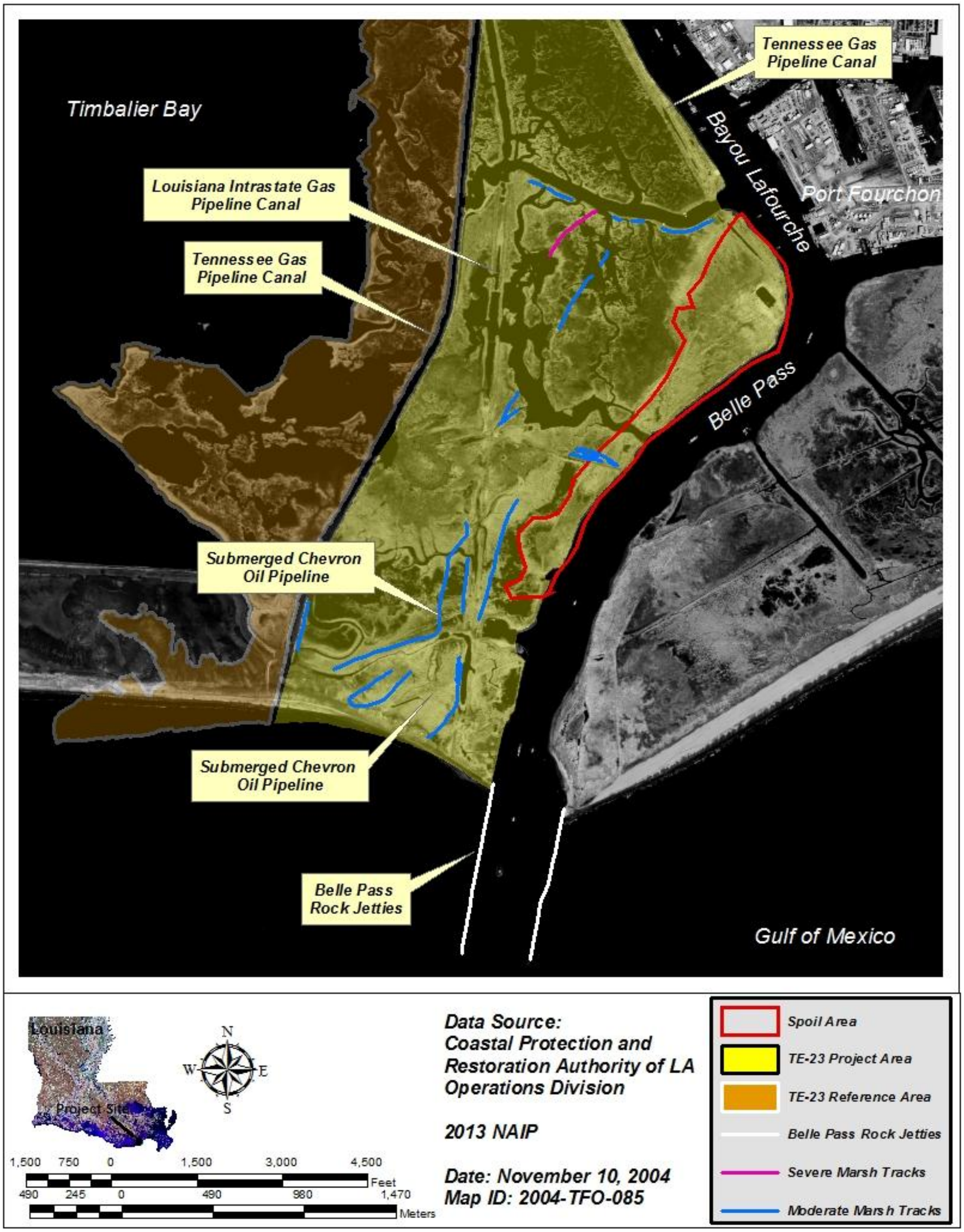

Figure 5. **Anthropogenic modifications affecting hydrology and sediment distributions at the West Belle Pass Headland Restoration (TE-23) project. These alterations predate the project except for the marsh tracks which were formed during construction in 1998.**

m (-20 ft) MLG depth and a 91 m (300 ft) wide extent in 1975. In 1980, the jetties were extended to their current 793 m (2,600 ft) length and 366 m (1,200 ft) width (Figure 5). Finally, the navigation channel was dredged to a -8.2 m (-27 ft) MLG depth in 2001 (D. Breaux, GLPC, pers. comm.). As previously discussed, the construction of these rock jetties disrupted the longshore transport processes along the Caminada-Moreau Headland considerably reducing the sand and sediment supply available to project area beaches (Harper 1977; Dantin et al. 1978; Boyd and Penland 1981; Penland and Suter 1988; Ritchie and Penland 1988b; Stone and Zhang 2001). In addition, a second consequence of navigation channel expansion was caused by the establishment of a highly elevated spoil area (Figure 5) along the project area shoreline prior to 1972 (Harper 1977). Moreover, this spoil bank was formed by disposing dredged materials onto the existing marsh surface causing the project area to become semi-impounded. The project area was further modified by construction of three pipeline canals and two submerged pipelines between 1952 and 1972 (Harper 1977; Williams et al. 1992). The pipeline canals also impounded and probably induced tidal scouring in project area marshes (Gagliano and Wicker 1989). The elevated spoil bank, the pipeline canals, and the submerged pipelines aided in the destruction of the remaining remnants of the western Belle Pass sand ridges and disrupted the natural hydrology of project area marshes (Ritchie 1972). Moreover, semi-impounded and impounded marshes have been found to prolong the recovery period after hurricanes and experience more severe and long-term impacts (Conner et al.1989). As a result, these anthropogenic modifications to the Belle Pass area have substantially contributed to the 3.1 m/yr (10 ft/yr) shoreline and marsh edge erosion rate experienced from 1932-1983 (Figure 6) (May and Britsch 1987).

The West Belle Pass Headland Restoration (TE-23) project consists of two major features, shoreline protection structures and a marsh creation area. The following synopsis was summarized from the TE-23 project completion report (USACE 1998). The shoreline protection phase of this restoration project extends for approximately 5,182 m (17,000 ft) along the western bank of Belle Pass and Bayou Lafourche (Figure 7). This phase of this restoration project includes the construction of a flotation channel, a foreshore rock dike, two rock closures, and a submerged rock weir (Figure 7). The marsh creation phase of the TE-23 project consists of an earthen retention dike, three earthen closures, and three disposal areas (Figure 7). For discussion purposes the marsh creation area was subdivided into three distinct areas, the closure 1, closure 3, and closure 5 marsh creation areas. First, the closure 1 marsh creation area is irregular shaped and generally forms its western border with the eastern bank of a Tennessee Gas Pipeline Canal, its northern border with the southern bank of Evans Canal, its eastern border with a preexisting spoil area (Figures 5 and 7), and its southern border lies directly south of closure 1. Next, the closure 3 marsh creation area generally forms its western border with the eastern bank of a Tennessee Gas Pipeline Canal, its eastern border with the Louisiana Intrastate Gas Pipeline Canal, and its southern border with the Gulf of Mexico (Figure 7). Finally, the closure 5 marsh creation area forms its western border with the southern portion of the Louisiana Intrastate Gas Pipeline Canal, its eastern border with closure 5, and its southern border with the Gulf of Mexico (Figure 7). Construction of the West Belle Pass Headland Restoration (TE-23) project began on February 10, 1998 and was completed on July 17, 1998.

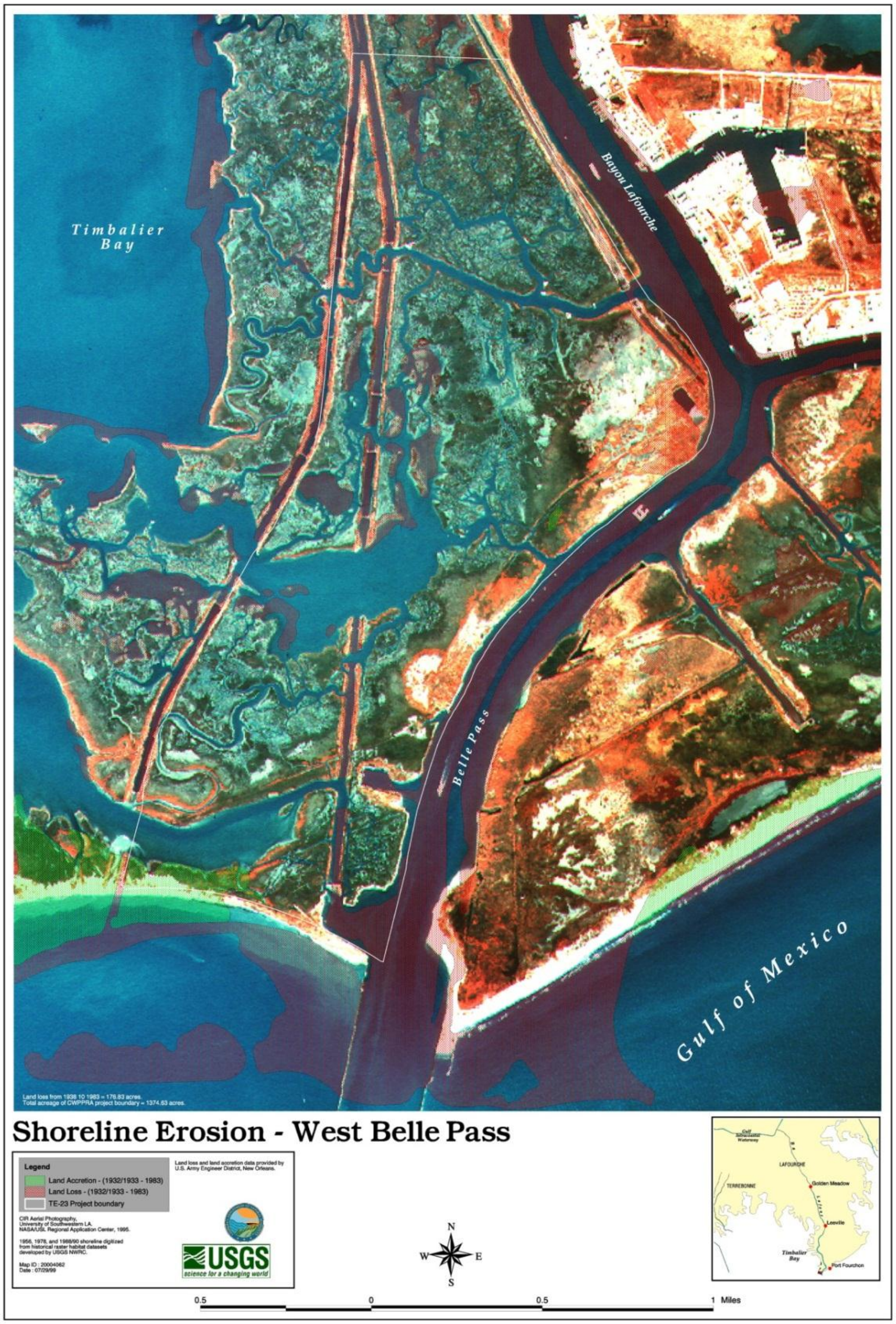

Figure 6. **Historic shoreline erosion data from the USACE (1932-1983) at the West Belle Pass Headland Restoration (TE-23) project. Data extracted from May and Britsch (1987) digitized erosion maps.**

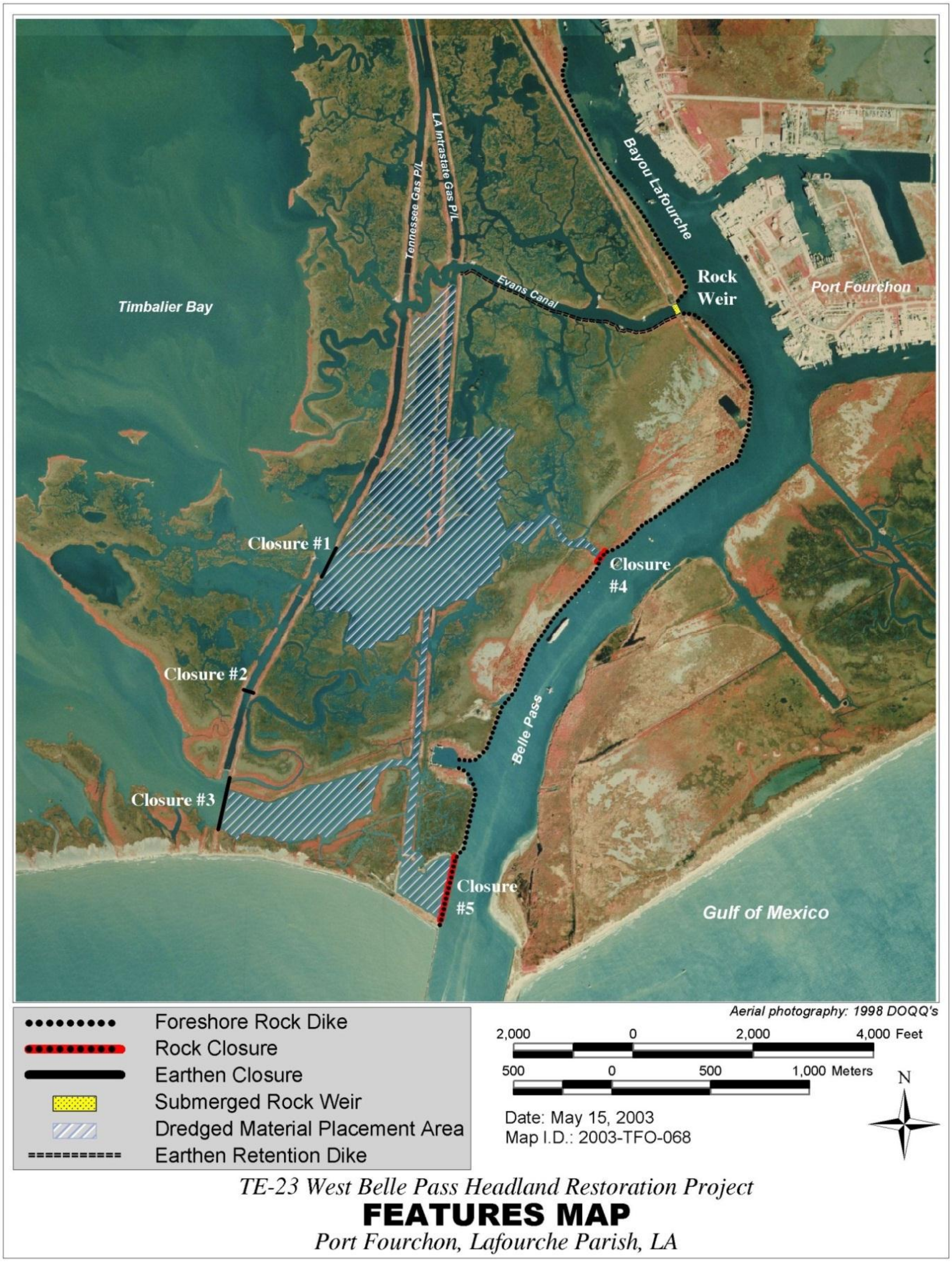

Figure 7. **Location of the West Belle Pass Headland Restoration (TE-23) project features. Note earthen closure #1 was re-constructed using sheet piles in 2007.**

To access the shallow areas close to the shoreline while constructing the foreshore rock dike, a 22.9 m (75 ft) wide flotation channel was dredged to a maximum depth of -2.4 m (-8 ft) Mean Low Gulf (MLG) along the entire length of the rock structure using a 4.6 m^3 (6 yd^3) bucket dredge. The sediments dredged from the flotation channel were stacked behind the foreshore rock dike creating an elevated spoil bank directly behind the rock structure (Figure 7). Approximately, 15,750 m^3 (20,600 yd^3) of benthic sediments were displaced to create the flotation channel. The construction of the flotation channel began on February 23, 1998 and was completed on April 12, 1998.

The 5,182 m (17,000 ft) foreshore rock dike and rock closures 4 and 5 were constructed along the -0.6 m (-2.0 ft) MLG shoreline contour by placing armor stone material on top of a geotextile foundation using a 3.8 m^3 (5.0 yd^3) bucket dredge (Figure 7). The dike and rock closures were built to a 1.8 m (6.0 ft) MLG elevation with side slopes of 1.5H:1V and were placed at least 6.1 m (20.0 ft) from the edge of the flotation channel. The geotextile foundation was allowed to extend 1.5 m (5.0 ft) beyond the toes of the rock dike and closures. Settlement plates were installed on 152 m (500 ft) intervals along the length of the rock dike and at the endpoints of the rock closures. An estimated 37,738,890 kg (46,100 tons) of armor stone and 42,224 m^2 (50,500 yd^2) of geotextile material were used to construct the rock structures. The construction of the rock dike and closures began on February 28, 1998 and were completed on April 16, 1998.

A 12.2 m (40 ft) wide 0.6 m (2 ft) thick submerged rock weir was constructed across Evans Canal by placing armor stone material on top of a geotextile foundation using a 3.8 m^3 (5 yd^3) bucket dredge. This rock weir was centered on the Tennessee Gas Pipeline crossing at Evans Canal near Bayou Lafourche and linked the pre-existing pipeline dams together (Figures 5 and 7). The geotextile foundation was allowed to extend 1.5 m (5 ft) beyond the toes of the rock weir. The construction of the rock weir began on March 11, 1998 and was completed on March 12, 1998.

An earthen retention dike and three earthen closures were constructed to contain the dredged material effluent within the marsh creation areas. The earthen retention dike was constructed along the southern banks of Evans Canal extending from the submerged rock weir to the Louisiana Intrastate Gas Pipeline Canal while the earthen closures were constructed along the western Tennessee Gas Pipeline Canal (Figure 7). These earthen structures were built to an elevation of 1.5 m (5 ft) MLG with a 1.5 m (5 ft) wide crown and side slopes of 3H:1V. The containment dike and closures were built on top of a 200 lb/in geotextile foundation with 1.5 m (5 ft) extensions and were constructed using sediments bucket dredged [4.6 m^3 (6 yd^3) bucket] from Evans Canal (earthen retention dike) and the marsh creation areas (closures 1, 2, and 3). The earthen retention dike and closure 1 were constructed with a barge mounted dredge while closures 2 and 3 were constructed with a marsh buggy mounted dredge. Moreover, a flotation channel of unknown dimensions was dredged across the closure 1 marsh creation area to construct earthen closure 1. The construction of the earthen retention dike and closures began on February 15, 1998 and were completed on April 3, 1998. Following construction and sediment consolidation, the earthen retention dike was breached in two locations to reestablish tidal inlets for fisheries access.

Once construction of the retention dike and closures were complete, marsh creation activities were initiated from maintenance dredging of the Bayou Lafourche navigation channel. The 91.4 m (300 ft) wide navigation channel was dredged from a depth of -6.1 m (-20 ft) MLG to a depth of -8.2 m (-27 ft) MLG using a 76.2 cm (30 in) hydraulic dredge. Channel maintenance began by dredging the reach from centerline (C/L) station 235+00 to C/L station 280+00 (navigation channel between the Belle Pass Rock Jetties) (Figure 5). Maintenance dredging activities were also conducted from C/L station 202+75 to C/L station 214+20 (navigation channel between Chevron Oil Pipelines) (Figure 5), from C/L station 151+45 to C/L station 193+10 (navigation channel in the vicinity of closure 4) (Figure 7), and from C/L station 76+85 to C/L station 92+65 (navigation channel in the vicinity of the northern limit of the foreshore rock dike) (Figure 7). 941,480 m^3 (1,231,409 yd^3) of benthic sediments were removed from the navigation channel and placed in the marsh creation areas to an elevation of at least 0.84 m (2.75 ft) MLG. An additional 174,319 m^3 (228,000 yd^3) of dredged material were removed from the navigation channel and deposited outside the project area on the West Belle Pass Beach (Figure 3). Channel dredging and marsh creation began on May12, 1998 and were completed on June 13, 1998 while dredge pipe and spill box removal were not concluded until July 17, 1998.

A 2007 maintenance event was undertaken to enhance the TE-23 project and to remove shoaling from the federal channel (Bayou Lafourche and Belle Pass). The completion report (USACE 2007) for this maintenance details the specifics of this event and was applied to write the summation below. During this event, dredged materials were deposited into the marsh creation area and the West Bell Pass beach and closure 1 was re-constructed with sheet pile. While dredging operations were in progress, the sheet pile wall collapsed in the center of closure 1. Because the sheet pile wall buckled, the remaining dredged materials were pumped onto the West Belle Pass Beach. Approximately, 325,855 m^3 (426,202 yd^3) of dredged material were placed into the closure 1 disposal area and 85,259 m^3 (111,515 yd^3) were added to the West Bell Pass Beach. A second 2007 maintenance event was initiated to repair damages to the sheet pile wall and install batter piles in the center of closure 1. The repaired sheet pile wall (closure 1) was damaged for a second time by the passage of Hurricanes Gustav and Ike in September 2008. The sheet pile wall has remained in disrepair since that time.

A second headland restoration project, the West Belle Pass Barrier Headland Restoration (TE-52) project, was constructed on the western Caminada-Moreau Headland in 2013. This beach, dune, and marsh creation project partially overlapped the southern footprint of the TE-23 project and reference areas (Figures 1 and 2). This CWPPRA project was federally sponsored by the National Marine Fisheries Service (NMFS) and locally sponsored by CPRA. The finer points of the TE-52 construction process are documented below and were extracted from the Devisse and Thomson (2013) completion report. The TE-52 beach fill extended the project area southward and westward. Beginning on the western template of the beach and dune fill area, the sand was shaped into a dune feature with a 2 m (6.5 ft) NAVD88 centerline elevation. The dune was shaped to this elevation for approximately two-thirds of its original project template. The remaining eastern sections of the dune were built to a 2.3 m (7.5 ft) NAVD88 centerline elevation. The approximate volume used to fill the beach and dune template was 2,041,361 m^3 (2,670,000 yd^3). In addition to the original beach and dune template, the beach and dune features were extended eastward to tie-in with a USACE, Beneficial Use of Dredge Material (BUMP) project that was pumping dredged materials on to the West Belle Pass Beach. The BUMP project began by placing dredged materials on the edge of the Belle Pass Rock Jetties and moved westward. The expanded beach and dune template resulted in a constructed dune with a 1.4 m (4.5 ft) NAVD88 centerline elevation. A change order was issued to construct this additional beach and supratidal feature due to potential sand loss between the two projects and to create a continuous beach from the rock jetties to the western limits of the TE-52 project. The added features increased the project's sand volume by 57,147 m^3 (74,745 yd^3). Therefore, the in place volume of sand rose to 2,098,508 m^3 (2,744,745 yd^3). On August 29, 2012 ten days after completing the beach and dune segments of the project, Hurricane Isaac made landfall on the Caminada-Moreau Headland (Figure 4) and breached the dune and the primary containment dike. The breach in the primary dike was closed by constructing a 61 m (200 ft) metal sheet pile wall with 9 m (30ft) deep sheet piles. The dune breach was plugged using heavy equipment and sand that had been over washed into the marsh creation area. Marsh creation activities commenced immediately following the passage of Hurricane Isaac. Silt and clay sediments were placed in the area between the beach and dune area's northern extents and the primary containment dike. Sediments in the marsh creation area were pumped to a final elevation range of 1.0-1.7 m (3.3-5.5 ft) NAVD88. A total of 1,575,142 m^3 (2,060,208 yd^3) of sediments were placed into the marsh creation area creating 135 ha (334 acres) of marsh.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the West Belle Pass Headland Restoration (TE-23) project is to inspect the physical condition of each project feature and determine if any deficiencies exist that would affect or alter the evaluation of the project features. The inspection results are then used to produce an annual inspection report containing description of the features, field inspection findings, photographs taken during the inspection and an updated operations and maintenance budget for the upcoming three (3) years. Field inspection photographs are provided in in Appendix A and a summary of the three (3) year O&M budget can be found in Appendix B.

b. Inspection Results

An Inspection of the West Belle Pass Headland Restoration (TE-23) project was held on April 28, 2016 under overcast skies and warm temperature. In attendance were Benjamin Hartman and Glen Curole with CPRA, Susan Hennington and Kaitlyn Carriere representing USACE-MVN. We departed from the Fourchon public boat launch at approximately 9:30 a.m. The inspection began at Closure #5 along Bell Pass, progressed along the shoreline protection feature along the west bank of Bayou Lafourche and Belle Pass, and concluded at the Closure #1.

The field inspection included a visual inspection of constructed features that were accessible by boat, including the vinyl bulkhead Closure #1, the rock shoreline protection and rock closures (Closures # 4 & 5) along Bayou Lafourche and Belle Pass. The interior marsh creation area was viewed from the perimeter of the project area. Closures #2 and #3 were inaccessible by boat and were not included in the 2016 inspection. Photographs of project features were taken during the field inspection and are shown in Appendix B.

<u>Wetland Restoration Area</u>

Material from Bayou Lafourche / Belle Pass maintenance dredging was pumped into the Wetland Restoration Area located between the Tennessee Gas Pipeline canal (western project boundary) and Belle Pass (eastern project boundary) in early 2007 as described above. It was reported in 2009 that the material placed at this location was well vegetated and that there was some tidal exchange with Timbalier Bay through the opening in Closure #1, but overall, the placed material appeared to be in stable condition. During the 2016 visual inspection of this area there was no significant difference from the 2013 inspection. This indicates that although there is still some tidal exchange the area remains fairly stable. Overall, the marsh appears to be healthy and thriving in this area.

Earthen Closures (Closures #1, #2, and #3)

Closure #1 was originally constructed as an earthen closure located along the east bank of the Tennessee Gas Pipeline canal that forms the western boundary of the project area. It was constructed in line with the east bank of the pipeline canal. All of the original earthen Closure #1 had breached and eroded due to tidal exchange between Timbalier Bay and the project wetland restoration area. In order to facilitate the placement of the maintenance dredged material in 2007, this closure was reconstructed as a vinyl sheetpile wall. In 2008, Closure #1 was breached as a result of the tidal surge associated with Hurricane Ike. The width of the breach is approximately 75 feet. The water depth at the breach was sounded and recorded at approximately 18 feet indicating a deep scour from tidal exchange through the breach. Other damage along the length of the bulkhead was noted as well, including bolt pullout, timber whaler damage, and localized sheetpile deflection in some areas. The 2016 inspection revealed similar conditions noted in 2013, following Hurricane Ike. Although the vinyl bulkhead is damaged, it doesn't appear to be a detriment to the project since the remaining marsh behind the structure seems to be stable at this time. Therefore, we are not recommending replacement of Closure #1 and will continue to monitor the condition of the vinyl bulkhead and interior marsh on future site visits (Photos 1 – 5).

Closures #2 and #3 were not inspected from the ground during this inspection due to access limitations. Access from the south near Closure #3 was also inaccessible due to the construction of the West Belle Pass Barrier Headland Restoration (TE-52) project. The reconstruction of the marsh and dune at the Gulf Shoreline, which encompasses Closure #3, should provide added protection from Gulf waters penetrating the interior marshes of the project from the south. With the construction of the TE-52 project, there is no need at this time to repair or rehabilitate Closures #2 or #3.

Evans Canal Weir (2' Lining)

The rock weir at the entrance to Evans Canal from Bayou Lafourche could not be visually inspected as it is a submerged, 2-foot thick, rock lift along the channel bottom in Evans Canal at the intersection with the eastern Tennessee Gas Pipeline canal. The bank tie-ins of the weir intersect the shoreline protection rock along the banks of Evans Canal and are in good condition. The foreshore rock at the east end of Evans Canal is also in good condition (Photo 10).

Shoreline Protection

The rock shoreline protection along the west bank of Bayou Lafourche and Belle Pass is in good condition with no signs of significant settlement. There is a low area of rock located just north of Closure #5 and at the entrance to Closure #4. Although there appears to have been some settlement, this area has not changed much since the 2013 inspection. This area remains stable and there are no recommendations for corrective actions at this time (Photos 6 - 12, 15 - 20).

Rock Closures (Closures #4 and #5)

The rock closures, Closures #4 and #5, located in line with the shoreline protection rock along the west bank of Belle Pass are in fair to good condition with no signs of significant settlement. We did notice a slight displacement of the riprap along Closure #4 which appeared in photos taken during previous inspections. Although there is slight displacement of the rock material, the structure seems to be in stable condition with no obvious breaches (Photos 13 - 14, 21 - 22).

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs

No current maintenance events are planned for the TE-23 project.

ii. Programmatic/ Routine Repairs

No current maintenance events are planned for the TE-23 project.

d. Maintenance History

August 2007 – Additional fill material was placed in the marsh creation area using dredged material from the maintenance dredging of Bayou Lafourche and Belle Pass. As part of the contract, Closure #1 was reconstructed as a vinyl sheet pile bulkhead. Construction began in November 2006. Construction of this event was completed in August 2007. The prime contractor for this project was Weeks Marine, Inc. who performed the dredging and placement of material. The subcontractor, Grand Isle Shipyard, Inc., performed the Closure #1 construction. The total construction cost for this project was $4,582,451.10 as reported in the U.S. Army Corps of Engineers Project Completion Report. The only construction items that were paid for through the TE-23 project were the Access Road and Closure #1. Remaining construction funds from the original TE-23 project (approximately $840,000) and approximately $290,000 of the O&M budget was applied toward the Access Road and Closure #1 construction items.

III. Operations Activity

a. Operation Plan

There are no operations for the TE-23 project.

b. Actual Operations

There are no operations for the TE-23 project.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS-*Wetlands*) for CWPPRA, updates were made to the TE-23 Monitoring Plan to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. CRMS0292 is located within the TE-23 reference area.

a. Monitoring Goals

The West Belle Pass Headland Restoration (TE-23) project will test the efficacy of utilizing navigation channel sediments, so called beneficial use of dredged materials (BUMP), to create saline marsh environments and the effectiveness of using a foreshore rock dike to slow the rate of shoreline transgressions along a navigation channel. The objectives of this project are to reduce the encroachment of Timbalier Bay into marsh on the west side of Bayou Lafourche and Belle Pass by creating 184.0 acres (74.5 ha) of wetlands and to prevent further shoreline retreat along the west bank of Belle Pass and Bayou Lafourche using armor stone.

The specific measurable goals established to evaluate the effectiveness of the project are:

1. Create approximately 184 acres (74.5 ha) of marsh on the west side of Belle Pass through infilling of designated canals and shallow water bodies.

2. Increase the marsh to open water ratio.

3. Decrease the rate of shoreline retreat along the west bank of Belle Pass and Bayou Lafourche.

b. Monitoring Elements

The following monitoring elements will provide the information necessary to evaluate the specific goals listed above:

<u>Land/Water</u>

The U.S. Geological Survey's Wetland and Aquatic Research Center (USGS/WARC) obtained 1:12,000 scale color infrared (CIR) aerial photography to delineate habitats and/or land/water environments over time. These aerial images were classified and photo-interpreted to perform land/water analysis of the West Belle Pass Headland (TE-23) project [542 ha (1340 acres)] and reference [652 ha (1611 acres)] areas. A pre-construction aerial photograph was acquired on November 8, 1997 while post-construction photographs were acquired on November 19, 2001, October 29, 2008, and November 1, 2012 (Figures C-1, C-2, and C-3 of appendix C). Aerial photographs were scanned at 300 pixels per inch and georectified using ground control data collected with a global positioning system (GPS) and digital ortho quarter quads. These individually georectified frames were assembled to produce a mosaic of the project area.

Using the National Wetlands Inventory (NWI) classification system, the 1997 and 2001 photography were photointerpreted by USGS/WARC personnel and classified to the subclass level (Cowardin et al. 1979). The habitat delineations were transferred to 1:6,000 scales mylar base maps and digitized. After being checked for quality and accuracy, the resulting digital data were analyzed using geographic information systems (GIS) to determine habitat change over time in the project area. The habitat types were aggregated into twelve habitat classes for the purpose of mapping change. Habitat changes inside the project and reference areas were calculated for the following interval 1997-2001.

Habitat classes were combined further to assess land to water changes in the project area. Habitats were condensed to a land or water classification in 1997 and 2001 using the Steyer et al. (1995) protocol. Land was considered to be a combination of marsh, upland, urban, forested, and scrub-shrub habitats. The beach/bar/flat, open water, and submerged aquatics (SAV) classes were considered water. Once grouped into these two classes, the percentage of land and water for each time period was calculated and the land to water ratio for each time period was calculated.

While the 1997 and 2001 land/water classifications were aggregated from NWI habitat delineations, the 2008 and 2012 images classified with a land/water methodology. Using the ERDAS Imagine® geographic information systems (GIS) remote sensing package, each pixel of the photo-mosaic was analyzed and classified to determine land to open water ratios using the land/water procedure described in Jones and Garber (2012). Specifically, habitats were condensed to a land or water classification. Land was considered to be a combination of marsh, upland, urban, forested, and scrub-shrub habitats. The open water, beach/bar/flat, and submerged aquatics (SAV) habitat classes were considered water. Once grouped into these two classes, the acreages of land and water were calculated. After the analysis was complete, the classification data and the photomosaic were mapped to spatially view the data. The percentages of land and water and the land to water ratios were also determined to summarize the data.

Shoreline Change

Shoreline position data were analyzed to estimate shoreline changes along the TE-23 project's Gulf of Mexico shoreface using the Digital Shoreline Analysis System (DSAS version 2.1.1) extension of ArcView® GIS (Thieler et al 2003). Pre- and post-construction change rates were calculated for the project and reference areas (Figures 1, 2, and 3) independently. Shoreline positions were determined by digitizing aerial photographs at a 1:800 scale as per the Steyer et al. (1995) method, which defines shoreline position as the edge of the live emergent vegetation. The resulting polylines established the shoreline positions in UTM NAD 83 coordinates. Pre-construction and post-construction aerial photographs were acquired over a sixteen year period to determine the shoreline erosion rates over time. A pre-construction aerial photograph was collected on November 8, 1997 while post-construction aerial photographs were captured on November 19, 2001 (3 years post-construction), November 1, 2005 (7 years post-construction), September 20, 2007 (9 years post-construction), October 29, 2008 (10 years post-construction), July 12, 2010 (12 years post-construction), November 1, 2012 (14 years post-construction), and November 12, 2013 (15 years post-construction). All images were georectified using UTM NAD 83 horizontal datum.

The November 1997 shorelines were created in ArcView® GIS software to establish pre-construction shoreline change rates for the project and reference areas, and the November 2001, November 2005, September 2007, October 2008, July 2010, November 2012, and November 2013 shorelines were created to establish post-construction shoreline change rates. Once the shorelines were delineated a baseline was generated and simple transects were cast at 50 m (164 ft) intervals producing shoreline change, intersect, and transect shapefiles. These shapefiles were edited by eliminating transects that intersect the shorelines at irregular angles. Shoreline change data were imported into Excel® to calculate average and annual erosion rates for each period. Shoreline change rates were assessed and mapped for the ensuing periods November 1997-November 2001, November 2001-November 2005, November 2005-September 2007, September 2007-October 2008, October 2008-July 2010, July 2010-November 2012, and November 2012-November 2013 for the Gulf of Mexico project and reference area shorelines. Shoreline analyses consisted of one-way ANOVA's. The statistical package used was JMP (v10).

Vegetation

Vegetation data was collected at the CRMS0292 reference site (Figure 3) to document species composition and percent cover over time. Ten (10) plots were placed inside the 200 m^2 (239 yd^2) square, which is nested within the 1.0 km^2 (0.4 mi^2) square, as per Folse et al. (2014). Vegetation data were collected in October 2008 (2 year post-construction), July 2009 (3 years post-construction), June 2010 (4 years post-construction), and July 2011 (5 years post-construction) via the semi-quantitative Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974; Sawyer and Keeler-Wolf 1995; Barbour et al. 1999). Plant species inside each $4m^2$ plot were identified, and cover values were ocularly estimated. After sampling the plot, the residuals within a 5 m (16 ft) radius were inventoried. Mean percent cover was calculated to summarize the vegetation data and was grouped by year. Floristic quality index (FQI) was also estimated using the Cretini and Steyer (2011) protocol. Site FQI assessments were derived using mean percent cover values and coefficient of conservatism (CC) scores.

Hydrology

Hydrologic data is also being collected at the CRMS0292 site. The CRMS0292-H01 station is located slightly outside the eastern margin of the TE-23 reference area (Figure 3). One (1) continuous recorder station was installed at this site to collect temperature (°C), specific conductance (μS/cm), salinity (ppt), and water level (ft) data on an hourly interval as per the Folse et al. (2014) protocol. The continuous recorder station was established on May 12, 2006 and has been under constant operation since that time. Yearly mean water level and salinity data were calculated to summarize the data collected from this hydrologic monitoring station during the period from May 2006 to December 2015. In addition, annual hydrologic indexes (HI) were calculated for this site using mean salinity, percent time flooded, and the saline marsh classification (Snedden and Swenson 2012). The HI scores are computed for a given water year, which begins October 1 and ends the following September 30.

c. Monitoring Results and Discussion

Land/Water

The land/water analyses show that the TE-23 project area is gaining land while the reference area's land area is consistently declining. Land/water percentages in the project and reference areas are graphically illustrated in Figure 8 for the duration of the assessment. Additionally, land/water acreages in the project and reference areas are shown in Tables 1 and 2 in hectare and acre units. The areal extent of the land/water or habitat coverages are presented for the 1997 (Figure C-1), 2001 (Figure C-1), 2008 (Figure C-2) and 2012 (Figure C-3) intervals in appendix C. The TE-23 project area exhibited a continued progression in land area over time (Figure 8 and Table 1) although these land expansions were derived through dredging events. Conversely, the reference area data reveals a slow but steady decrease in land area over the study period (Figure 8 and Table 2). Surprisingly, the TE-23 reference area continued to lose land area in 2012 after sediments were placed in the southern reaches of the reference area by the TE-52 project (Figures 8, C-2, and C-3). It appears that these sediment increases in the TE-23 reference area were not large enough to offset the

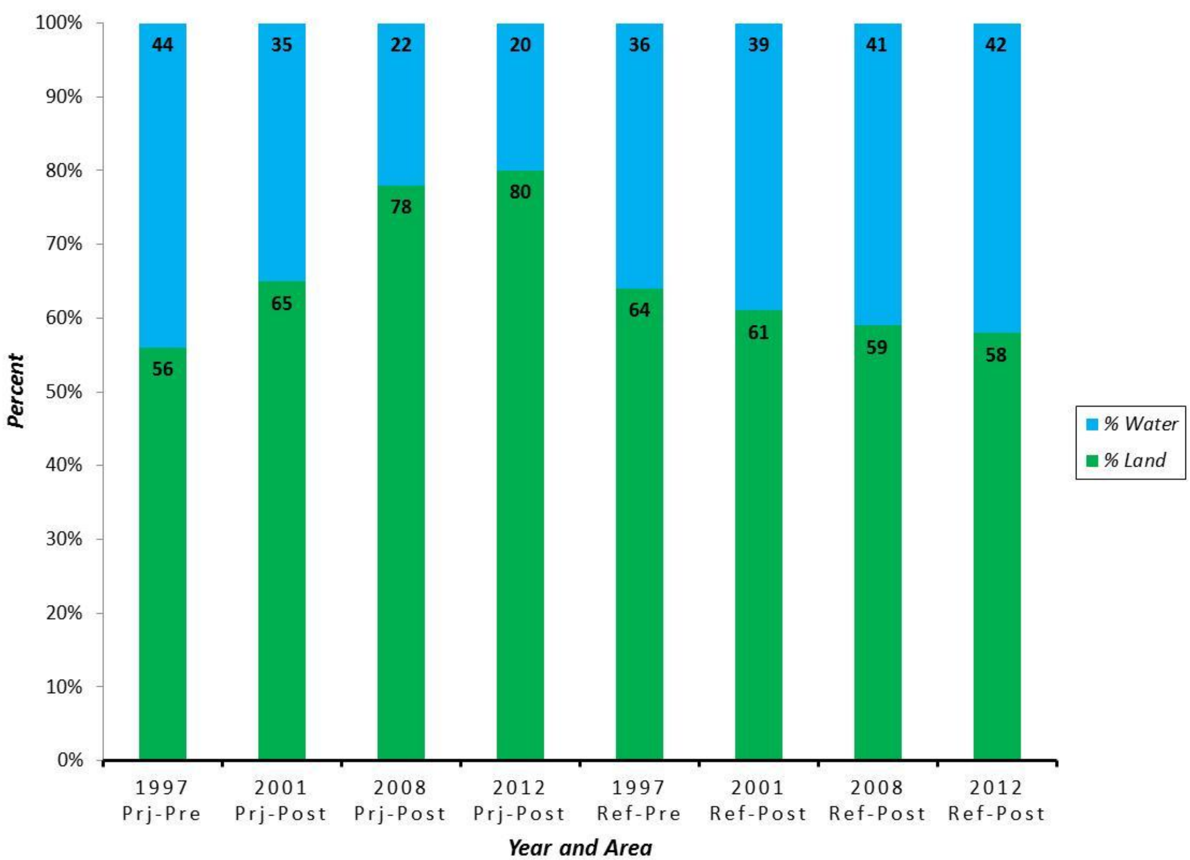

Figure 8. Percentage of land and water inside the West Belle Pass Headland Restoration (TE-23) project and references areas in 1997 (pre-construction), 2001 (post-construction), 2008 (post-construction), and 2012 (post-construction).

Table 1. **Land/water acreages and changes photo-interpreted from 1997, 2001, 2008, and 2012 aerial photography for the West Belle Pass Headland Restoration (TE-23) project area.**

Land/Water Project	*1997 Ha (Acres)*	*2001 Ha (Acres)*	*2008 Ha (Acres)*	*2012 Ha (Acres)*	*97-01 Change*	*01-08 Change*	*01-12 Change*	*97-12 Change*
Land	305 (753)	350 (866)	423 (1,045)	436 (1,078)	46 (114)	72 (179)	85 (212)	131 (325)
Water	238 (588)	192 (475)	119 (295)	106 (262)	-46 (-114)	-73 (-180)	-86 (-213)	-132 (-326)
TOTAL	543 (1,341)	543 (1,341)	542 (1,340)	542 (1,340)	0	-1	-1	-1

Table 2. **Land/water acreages and changes photo-interpreted from 1997, 2001, 2008, and 2012 aerial photography for the West Belle Pass Headland Restoration (TE-23) reference area.**

Land/Water Reference	*1997 Ha (Acres)*	*2001 Ha (Acres)*	*2008 Ha (Acres)*	*2012 Ha (Acres)*	*97-01 Change*	*01-08 Change*	*01-12 Change*	*97-12 Change*
Land	414 (1,024)	397 (979)	384 (950)	376 (929)	-18 (-44)	-12 (-30)	-21 (-51)	-38 (-95)
Water	238 (587)	255 (631)	267 (661)	276 (682)	18 (44)	12 (30)	21 (51)	38 (95)
TOTAL	652 (1,611)	652 (1,611)	652 (1,611)	652 (1,611)	0	0	0	0

amount of marsh edge and interior marsh erosion transpiring throughout this area. The greatest gains in the project area land occurred after the project construction (1998) and the 2007 maintenance event. These sediment additions increased the project land area by 9% and 13% while the construction of the TE-52 project only increased the TE-23 land area by 2% (Figure 8). These enhancements in land area correspond to land to open water ratios of 1.3:1.0 in 1997, 1.8:1.0 in 2001, 3.5:1.0 in 2008, and 4.1:1.0 in 2012. In contrast, the reference area land to open water ratios was reduced from 1.7:1.0 in 1997 to 1.4:1.0 in 2012. While the land acreage of the project area increased by 131 ha (325 acres) from 1997 to 2012 (Table 1), not all the land created in the project area was marsh or wetland habitats. The reference area land acreage decreased by -38 ha (-95 acres) for this period (1997-2012) (Table 2). Using the 1997 and 2001 habitat data (Figure C-1) to calculate marsh and wetland change percentages, marshes comprised 27% and wetland habitats constituted 92% of the project area land gains. Extrapolating these percentages forward to 2008 and 2012, the project area marsh and wetland habitats were estimated to have increased by 32 ha (79 acres) of marsh and 110 ha (273 acres) of wetlands in 2008 and by 36 ha (88 acres) of marsh and 121 ha (299 acres) of wetlands in 2012 (Table 1). The disparity between marsh and wetland habitats is primarily driven by the growth in *A. germinans* (black mangrove) habitats during the sampling period. Moreover, wetland scrub/shrub–salt habitat (*A. germinans*) displaced marsh habitat in many locations in the project, reference, and outlying (Perry 2007) areas. In fact, wetland scrub/shrub–salt habitat expanded by 32 ha (79 acres) in the project area and 19 ha (46 acres) in the reference area from 1997 to 2001 (Figure C-1). *A. germinans* is a critical wetland species that is well adapted to tropical and fringe subtropical coastal environments (Alleman 2010). This species provides valuable ecological services to coastal communities (Visser et al. 2005; Alleman 2010; Lee et al. 2014) and has not been found to alter *S. alterniflora* functioning in Louisiana (Perry 2007). Therefore, the created *A. germinans* and other wetland scrub-shrub acreage within the project area will be calculated as marsh for the purposes of goal attainment because these habitats provide essential ecosystem services and functions to this constructed saline community. The adjusted wetland to open water ratios advanced the wetland area in the project area from 1.2:1.0 in 1997 to 3.8:1.0 in 2012 whereas the reference area ratios increased the open water area from 1.7:1.0 in 1997 to 1.2:1.0 in 2012. As a result of the increased wetland acreage [121 ha (299 acres)] and wetland to open water ratios, the goals to create 184 acres (74.5 ha) of marsh and to increase the marsh to open water ratio were achieved. However, the goals were not realized during the initial TE-23 construction event in 1998. Actually, the wetland acreage created after this event was -38% below the stated goal and the TE-23 project was impaired by construction failures and adverse impacts derived from this initial marsh creation attempt (Curole and Huval 2005). Furthermore, if not for the fact that the TE-23 project was positioned next to a federally maintained channel (Bayou Lafourche), the 2007 maintenance event would not have taken place and the project goals would not have been attained. Not all marsh creation projects get a second chance to atone for goal underachievement due to the high costs associated with dredge and fill events, it is beneficial that the TE-23 project had a second chance to fulfill its goals.

The construction failures and adverse impacts that occurred during the initial TE-23 construction event in 1998 include volume deficits, marsh tracks, and elevated spoil embankments. These deficits and damages are detailed in the Curole and Huval (2005) report. The volume reductions are a result of breaching of earthen closures 1 and 3 (Figure 7) and the fact that less than half of the design volume of dredged material was pumped into the marsh creation areas. Moreover, the closure 3 creation area was not completely filled until 2012 by the TE-52 restoration project. Interestingly, the closure 1 structure also breached in 2007 after it was reconstructed with sheet piles. The sediment deficits appear to be a result of navigation channel depth being reached and channel volumes being over estimated. If marsh creation projects are to be successful, marsh creation not just navigation channel dredging and disposal, needs to be a priority (USACE 1987). Marsh buggies severely or moderately compacted 3.8 ha (9.5 acres) of vegetated wetlands (J. Harris, LDNR/CMD, pers. comm.). The severely compacted track still exists, has expanded over time (Figures 5, A-12, C-2, and C3), and has endured tidal scouring (Whitehurst et al. 1977; Detro 1978; Bass 1996; Bass 1997). The elevated spoil embankment that was created with flotation channel refuse impacted 3.2 ha (8.0 acres) of existing marsh (J. Harris, LDNR/CMD, pers. comm.). These permit violations were rectified using compensatory mitigation. However, no site remedial steps have been taken to date, and the problems created by the violations persist.

Although the TE-23 project did eventually satisfy its marsh creation goals over time, sizeable portions of the project area appears to have restricted hydrology and was filled unevenly. Close examination of 2013 aerial photography (Figure 5) reveal that the marsh creation project areas are semi-impounded due to pre-existing dredge spoil areas, pipeline canal spoil banks, and the flotation channel spoil bank. Several locations in the lee of the elevated spoil areas retain water and have a minimal amount of vegetative cover (Figure 5). The pipeline canal spoil banks and elevated portions of the marsh creation area also continue to impede water movement within and out the project area. Semi-impounded marshes inhibit tidal flushing, prolong the duration of flooding events (Swenson and Turner 1987), lower sediment and nutrient inputs (Kuhn et al. 1999), and inhibit fisheries access (Kutkhun 1966; Herke and Rogers1989; Perret and Melancon 1991). In addition, the elevated portions of the constructed marsh have very little vegetative cover probably due to high salt concentrations (Mitsch and Gosselink 2000; Edwards and Proffitt 2003) and incur very little tidal flushing while segments of the pipelines have not been filled completely (Figure 5). Perhaps the TE-23 project would have been better served by compartmentalizing the project area into smaller creation areas and filling when channel maintenance events are needed.

Shoreline Change

Although shoreline change along the TE-23 project's Gulf of Mexico shore is not a project goal, dredged materials have been placed on this shoreline on four occasions since the inception of the TE-23 project. The first two sediment additions occurred during TE-23 construction (1998) and maintenance (2007) events. During both incidents, sediments were targeted to be deposited in the TE-23 marsh creation area but were pumped on the western Belle Pass Beach due to breaching of the closure 1 structure (Figure 7). In other words, sediment additions to this shoreline were not planned and goals to assess feature performance were not established. The third dredging events added sediments to both the TE-23 project and reference Gulf of Mexico shorelines through the construction of the TE-52 and a BUMP project in 2012. These two projects were built almost simultaneously from May-Oct of 2012 and created beach, supratidal, dune, and/or marsh habitats within the TE-23 project and reference footprints (Devisse and Thomson 2013; Curole et al. 2015). A fourth dredging event (another USACE, BUMP project) added sediments to the TE-23 project area beach in September 2015. The third TE-23 monitoring goal, to decrease the rate of shoreline retreat along the west bank of Belle Pass and Bayou Lafourche, does not refer to the project's Gulf of Mexico shore. This goal refers to the Belle Pass and Bayou Lafourche shoreline located behind the foreshore rock dike (Figure 7). No erosion was found behind this structure (Curole and Huval 2005) and the goal was eliminated from the monitoring design.

Post-construction TE-23 project and reference area shoreline position data for the Gulf of Mexico shore indicate that the shoreline expands with sediment inputs and transgresses in the absence of mineral additions. Figure 9 illustrates the changes to the southern TE-23 shoreline over seven post-construction intervals. This figure displays how dynamic the western Belle Pass shoreline has been over the course of the study period. Shoreline positions for these intervals can be viewed in Figures D-1 (project area) and D-2 (reference area) in appendix D. The project area prograded for periods with sediment additions, [the 1997-2001 interval (sediments added in 1998), the 2005-2007 interval (sediments added in 2007), and the 2010-2012 interval (sediments added in 2012)], and eroded for periods without. The volume of sediments placed for the 1998 [174,319 m^3 (228,000 yd^3)], 2007 [85,259 m^3 (111,515 yd^3)], and 2012 [approximately 2,000,000 m^3 (2,600,000 yd^3)] dredging events also had a corresponding effect on the shoreline change rates within the project area (Figure 9). Only a portion of the 2012 dredging volume was placed along the TE-23 project area Gulf of Mexico shoreline, another portion was placed in the TE-23 reference area, and a third portion was placed outside of the TE-23 boundaries. Spatially the project area had its greatest gains and losses in the shoreline transects closest to the Belle Pass Jetties (Figure D-1). The reference area only prograded for the 2010-2012 interval, the only period when sediments were directly added to the reference area shorelines. However, sediment additions during the 2005-2007 interval seem to have reduced erosion rates in the reference area (Figure 9) and are possibly a result of net longshore transport (Peyronnin 1962; Dantin et al. 1978; Ritchie and Penland 1988b; Stone and Zhang 2001; Thomson et al. 2009) (Figure 2). Conversely, the retention of the 1998 sediment addition within the project area through 2001 probably influenced the 1997-2001 erosion rates in the reference area (Figures 9, C-1, and D-1). The reference area tended to incur greater erosion along its western transects (Figure D-2). The influence of the 2002 (Hurricanes Isidore and Lili), 2004 (Hurricane Ivan and T. S. Matthew), 2005 (Hurricanes Cindy, Katrina, and Rita), and 2008 (Hurricanes Gustav and Ike) tropical storms (Figure 4) can be viewed in Figure 9 by examining the increased erosion during the 2001-2005 (project area) and 2007-2008 (project and reference areas) intervals. Moreover, Curole et al. (2015) assessed the western Belle Pass shoreline with elevation change grid models from 2008-2011 and found this shoreline to display shoreline erosion and cross-shore transport indicators in the aftermath of the 2008 hurricanes. Additionally, ephemeral washover fans are an almost omnipresent feature of this shoreline. Curole et al. (2015) also

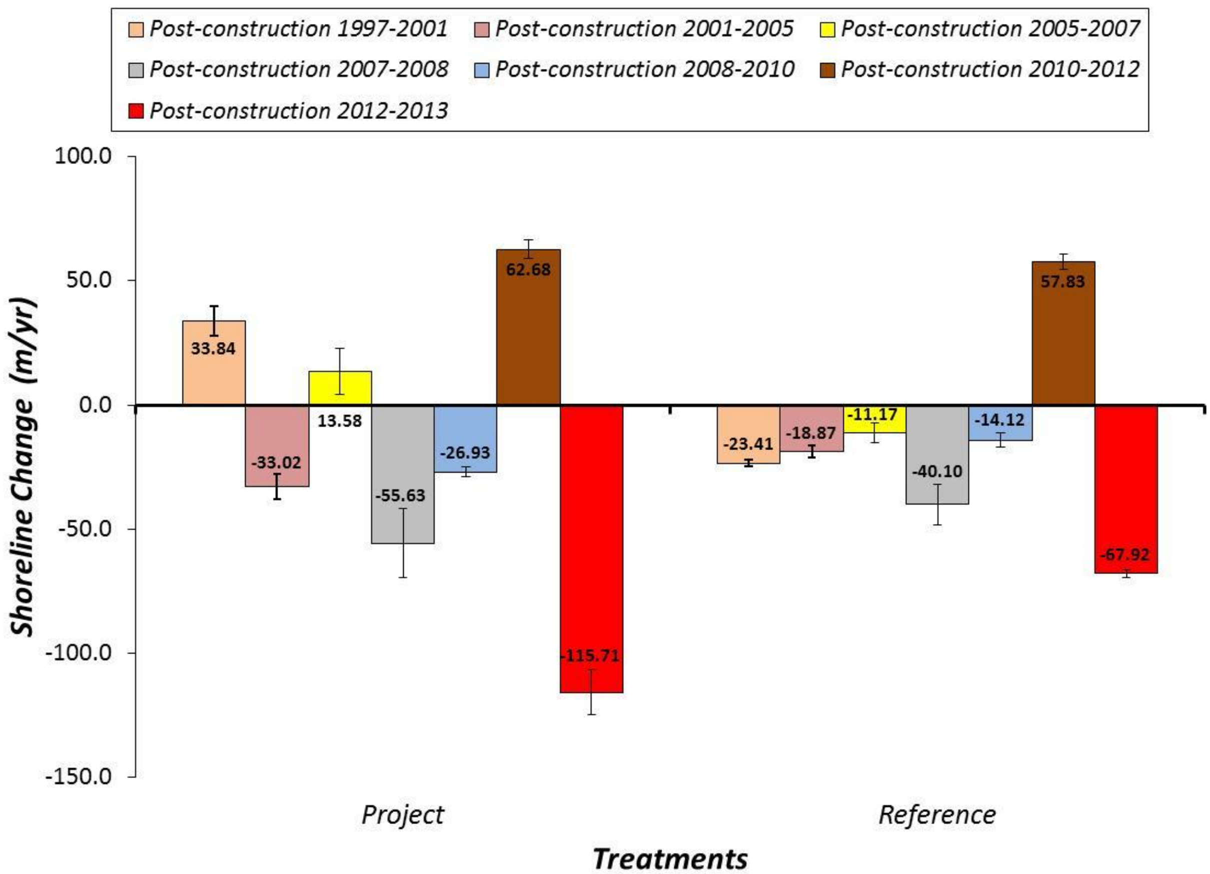

Figure 9. Shoreline change intervals for the West Belle Pass Headland Restoration (TE-23) project and reference area Gulf of Mexico shorelines from Nov 1997-Nov 2013.

surmised from further elevations change models (2012-2015) and oblique aerial photos that the passage of Hurricane Isaac (Figure 4) immediately after TE-52 beach and dune construction were complete probably accelerated shoreline transgressions in the TE-23 project and reference areas. Hurricane Isaac's impact on the TE-23 shorelines seems to masked in the 2010-2012 data due to the large amount of sediments added in 2012 (Figure 9). In addition to Hurricane Isaac, winter storms (Boyd and Penland 1981; Dingler and Reiss 1990; Ritiche and Penland 1998b; Georgiou et al. 2005), and the Belle Pass Rock Jetties (Dantin et al. 1978; Penland and Suter 1988; Curole et al. 2015) were likely influential in progressing the TE-23 shoreline transgressions for the 2012-2013 interval (Figure 9). All spatial and temporal differences between project and reference intervals were significant ($P < 0.05$). However, an analysis of project versus reference for the entire study period (combined data from all intervals) was not significant ($P > 0.05$). Interestingly, the combined mean erosion rate in the project area was -17.3 m/yr (-56.8 ft/yr) and -17.1 m/yr (-56.1 ft/yr) in the reference area. This seems to have occurred by chance because at no other point in the data were the running total of the project and reference area means that similar. In conclusion, the TE-23 project and reference area shorelines experienced shoreline expansions with sediment additions and shoreline erosion in periods without sediment input over the fifteen year study. The degree of shoreline transgressions was a consequence of the intensity and frequency of tropical and winter storm events that were exacerbated by the close and downdrift proximity of the TE-23 project to the Belle Pass Rock Jetties.

Vegetation

The CRMS0292 vegetation data confirms the classification of the TE-23 marsh creation area as saline marsh. The dominant species found were *S. alterniflora* and *A. germinans. Salicornia bigelovii* Torr. (dwarf saltwort) was the only other species found within the plots and occurred infrequently and provided very little cover (Figure 10). *S. alterniflora*, *A. germinans*, and *S. bigelovii* are common inhabitants and indicator species for saline marsh habitat (Chabreck and Condrey 1979; Gosselink et al. 1984). While *S. alterniflora* is typically the dominant species in Louisiana salt marsh communities, *A. germinans* has been expanding in the vicinity of the TE-23 project (Figure C-1; Perry 2007; Alleman 2010) and is enlarging its presence in the CRMS0292 vegetation plots as well (Figure 10). The vegetation sampling was generally conducted from late July through September when *S. alterniflora* standing crops are highest (Kirby and Grosselink 1976). Therefore, the cover inequalities over time are likely derived through annual differences in meteorological and environmental stimulates or stressors, which can spur or inhibit vegetative growth. The floristic quality index (FQI) seems to be governed by the mean vegetative cover because both *S. alterniflora* and *A. germinans* are assigned the maximum coefficient of conservatism (CC) values (Cretini and Steyer 2011). Figure 11 compares the annual FQI scores for the CRMS0292 site to the mean of all other CRMS saline marshes in coastal Louisiana. This graph shows that during the highest cover years the CRMS0292 FQI value approaches or equals the mean while during other years the site FQI falls below the mean but generally within the standard error. As a result, this salt marsh probably functions at a similar or a slightly reduced level as other saline marshes in Louisiana depending on annual growing conditions. In closing, the CRMS0292 vegetation data confirm that the TE-23 project and reference areas are salt marsh habitat.

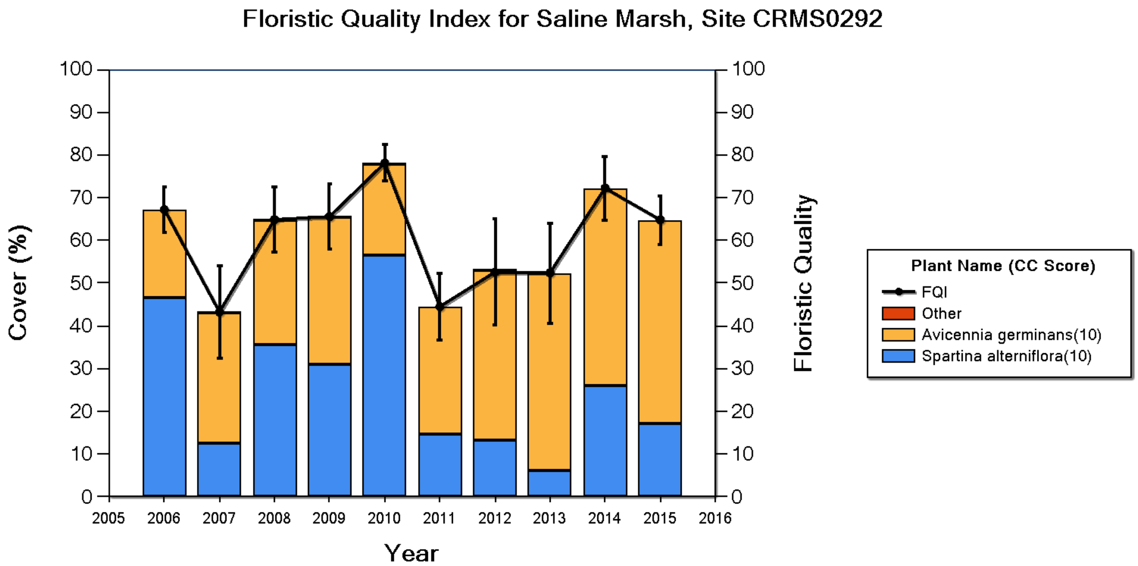

Figure 10. **Mean percent cover and floristic quality index (FQI) for vegetation species populating the CRMS0292 200 m2 (239 yd2) square from 2006 to 2015.**

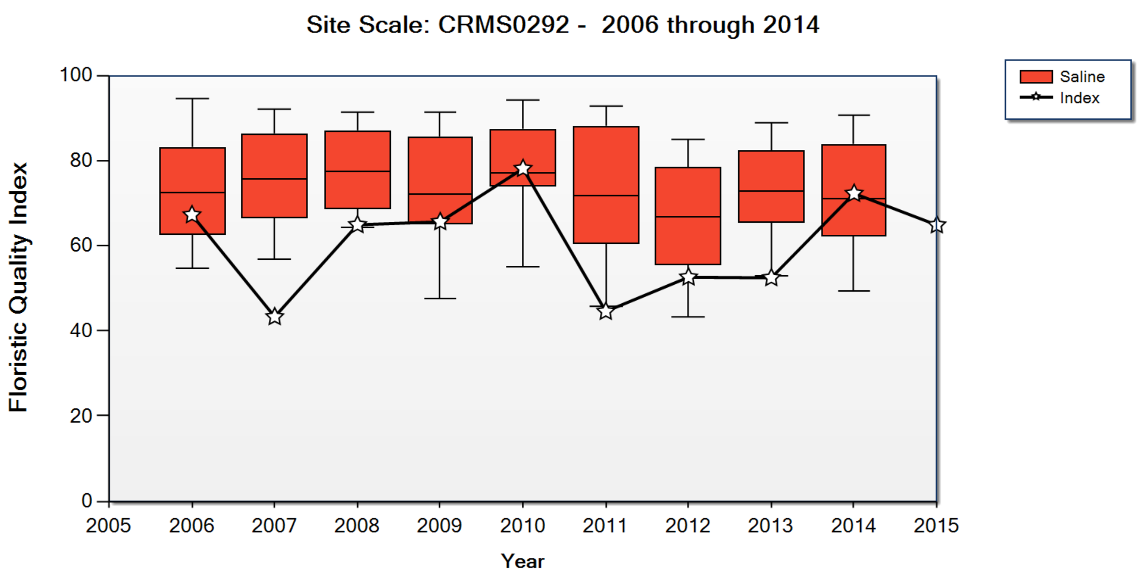

Figure 11. **Site scale distributions comparing the annual CRMS0292 FQI score to the mean of all CRMS saline marshes from 2006 to 2014.**

Hydrology

The CRMS0292 hydrologic data confirms the classification of the TE-23 project and reference areas as saline marsh. The mean salinity and water level for the period from May 2006 to December 2015 were 24.9 ± 4.07 ppt and 0.93 ± 0.002 ft (0.28 ± 0.001 m) NAVD 88. The yearly mean salinities are shown in Figure 12. The yearly mean salinities ranged from 26.6 ppt (2007) to 22.8 ppt (2010 and 2015). These salinity values fall within the range of a salt marsh classification (Steyer et al. 2008). The yearly mean water levels are outlined in Figure 13. These yearly means ranged from 0.23 m (0.77 ft) (2007) to 0.34 m (1.11 ft) (2015). The marsh elevation in the vicinity of CRMS0292 has been documented as having a 0.33 m (1.09 ft) NAVD 88 elevation. Therefore, the marshes are flooded only when the water level exceeds the mean water level. For the duration of the hydrologic data collection, the project area marshes were only flooded for less than 40% of the time. The hydrologic index (HI) scores hovers around 80 for the CRMS0292 site (Figure 14). For this site the HI score is driven by salinity. The score increases during low salinity years and decreases for high salinity years. Similar to the FQI scores, the HI scores approach the mean HI score for CRMS salt marshes for low salinity years and remains within the standard error for other years (Figure 14). The stability in the CRMS0292 vegetation community was influenced by the

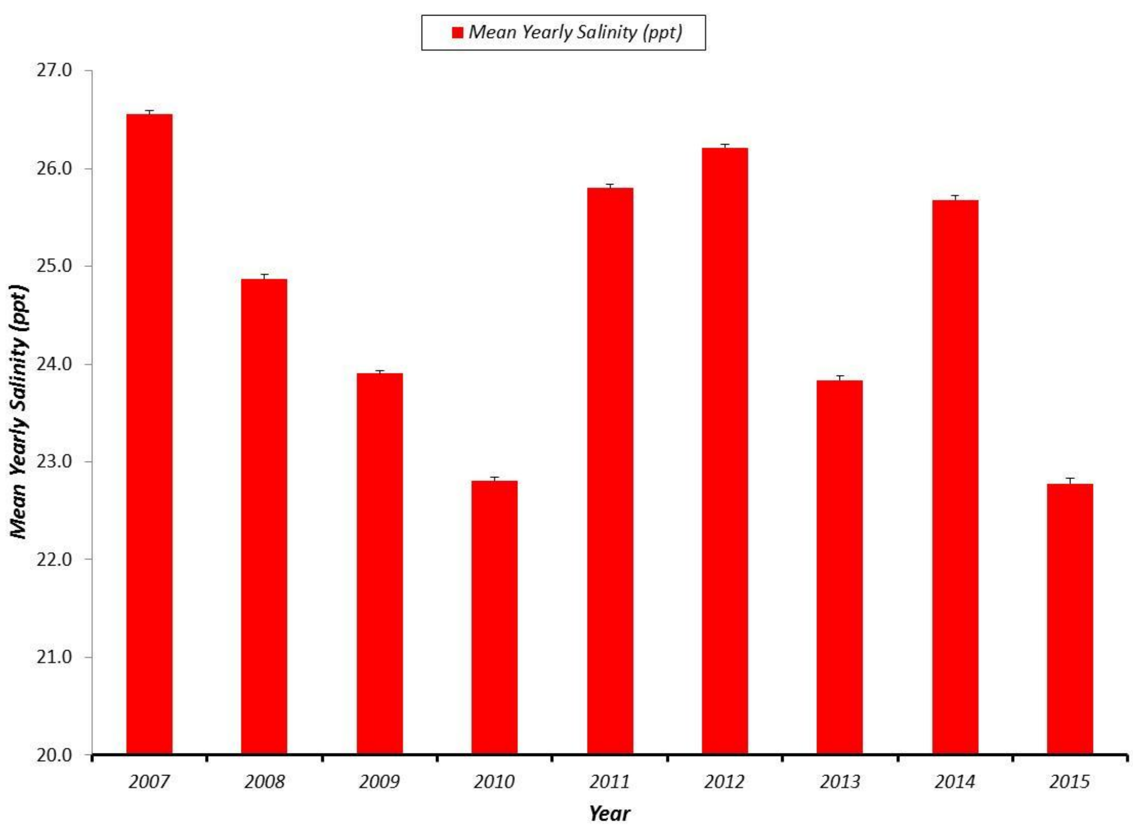

Figure 12. Post-construction mean yearly salinity (ppt) inside the CRMS0292 200 m2 (239 yd2) square from 2007 to 2015.

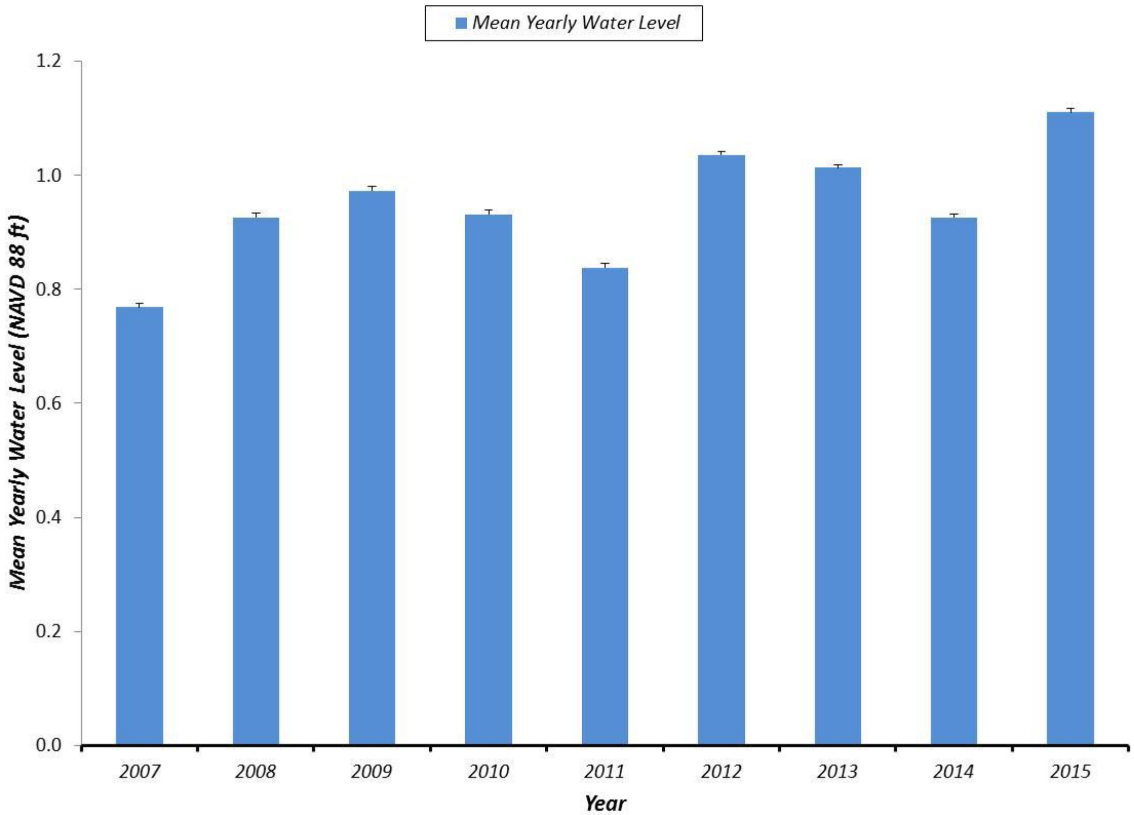

Figure 13. **Post-construction mean yearly water level (ft) inside the CRMS0292 200 m2 (239 yd2) square from 2007 to 2015.**

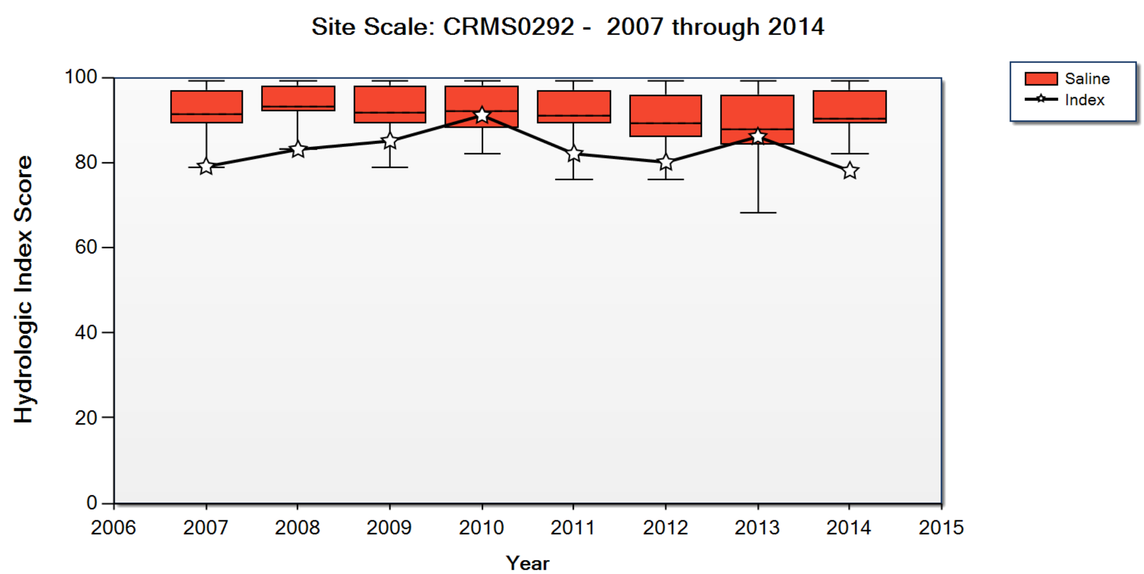

Figure 14. **Site scale distributions comparing the annual CRMS0292 HI score to the mean of all CRMS saline marshes from 2007 to 2014.**

salinity and the tidal regime. The mean salinity generally remained in the saline range and rarely spiked to brackish or marine salinities (Steyer et al. 2008). The tidal amplitude and elevation of the site encourage the vegetative growth in this plant community because the marshes are periodically drained during low tides (Eleuterius and Eleuterius 1979; McKee and Patrick 1988). Therefore, it is highly likely that these same conditions exist in the TE-23 project area only with higher wetland elevations and greater hydrologic restrictions due to pre-existing and constructed barriers.

V. Conclusions

a. Project Effectiveness

The results of the West Belle Pass Headland Restoration (TE-23) reveal that both of the project goals were attained to date. The first goal to create approximately 184 acres (74.5 ha) of marsh on the west side of Belle Pass through infilling of designated canals and shallow water bodies was realized because the wetland acreage created exceeded the goal requirements. Approximately, 121 ha (299 acres) of wetland habitat were created in the project area over time. Wetland habitats were included in the goal acreage because *A. germinans* (black mangrove) has been expanding and displacing saline marsh habitats in the project area, reference area, and in the surrounding marshes since project inception. Moreover, this woody species provides valuable ecosystem services and ecological functions to the project area marshes. However, the goals were not realized during the initial TE-23 construction event in 1998. The goal was not achieved until after the 2007 maintenance event, which considerably increased the wetland acreage within the project area. The TE-23 project was fortunate to be positioned in close proximity to the federally maintained Bayou Lafourche Navigation Channel because without the channel maintenance event this goal would not have been achieved.

The second goal to increase the marsh to open water ratio was also attained. The wetland to open water ratio was increased through an enlargement in wetland area and a reduction in open water area. The wetland to open water ratio expanded in the project area from 1.2:1.0 in 1997 to 3.8:1.0 in 2012. The reference area ratio decreased from 1.7:1.0 to 1.2:1.0 during the same period. Similar to the acreage goal, this goal could was substantially enhanced by the 2007 maintenance event.

The third TE-23 monitoring goal, to decrease the rate of shoreline retreat along the west bank of Belle Pass and Bayou Lafourche, was eliminated from the monitoring design in 2003. This goal was removed due to a system wide monitoring reduction to fund the CRMS reference network. While the goal was eradicated, the Belle Pass and Bayou Lafourche shoreline located behind the foreshore rock dike has not been subjected to noticeable shoreline erosion during the study period. Therefore, the foreshore rock dike is successfully protecting this shoreline.

b. Recommended Improvements

Amongst project features, the only noticeable damage is contributed to the sheet pile wall. The original function and need of the sheet pile wall was to serve as containment during pumping; after construction, the feature coincidentally served as a water control structure. Regardless of damage, the original purpose has been served and there will be no further recommendations to repair the structure or alter other project features.

c. Lessons Learned

Four restoration lessons were learned from the West Belle Pass Headland Restoration (TE-23) project. The first lesson is that two dredge and fill events were required to accomplish the acreage and ratio goals. Ideally, only one construction event should be necessary to create marsh or wetlands habitat. Moreover, meeting or slightly exceeding acreage and elevational requirements of a restoration project during a single construction event would be considerably more economical than conducting multiple events. Dredge and fill events are inherently expensive and these costs are inflating over time. Funding is generally not provided for multiple construction phases and maintenance funds rarely are sufficient to manage a second creation cycle. Therefore, it is more desirable to construct wetlands during a single dredge and creation event. To accommodate a single dredge and creation scenario for the TE-23 project, simultaneous reconstruction of the closure 1 and closure 3 breaches would have been required while the marsh creation areas were being filled during the 1998 construction event. In addition, to obtain the sediment volume needed to fill and elevate the TE-23 marshes, the dredge would have been required to excavate beyond the authorized channel depths of the federal navigation channel or extend its dredging reach to obtain more material- neither of which were options. As a result, the substantial overestimation of channel maintenance volumes inhibited the success of the TE-23 goals in 1998 and condensed dredged materials into a limiting resource. If the 1998 TE-23 construction event was not constrained in these ways and the closures had not failed, the project likely would have attained its goals after the first construction cycle. Marsh creation needs to be a priority - not just navigation channel dredging to achieve authorized depths - when attempting to construct wetlands with sediments dredged from navigation channels (USACE 1987). When wetland creation areas are located next to federally maintained navigation channels, like the TE-23 project, it is feasible to employ adaptive management measures and have multiple dredge and fill events as long as the fill areas are compartmentalized into separate creation areas, the creation events are well planned and site specific, valid channel volume estimates are acquired, and the required construction funds are provided. Furthermore, marsh creation acreage needs to be sized to fit the volume of shoal material required to reestablish authorized channel dimensions, thereby optimizing project goal attainment, acreage created, and funding requirements.

The second lesson is that permit violations should be rectified before construction is complete through site remediation. The TE-23 project area was damaged by construction activities during project construction in 1998. Specifically, marsh tracks were formed by marsh buggies and a spoil bank was built with material excavated to construct the flotation channel. These unwanted features of the project still exist and continue to impact vegetation and hydrology. The marsh buggy tracks and burial issues were resolved with the primary contractor depositing $100,000 in the Louisiana Wetlands Conservation and Restoration Fund. However, no attempts have been made to restore the compacted or buried marshes to date.

The third lesson is that the TE-23 project area was filled unevenly and had pre-existing barriers restricting hydrology. Portions of the marsh creation area were filled to higher elevations that have limited vegetative colonization and very low cover while segments of the pipeline canals have not been filled completely. Additionally, the existing project area before construction had several elevated features that inhibited hydrology. A wide and highly elevated spoil bank was created along the banks of Bayou Lafourche and Belle Pass prior to 1972 (Harper 1977) and three pipeline canals with elevated spoil banks were placed within or along the borders of the TE-23 project area (Figure 5). All these anthropogenic features impede water flow within or out of the project area. As a result, water is retained for long periods in low elevated semi-impounded areas (Swenson and Turner 1987) or is not allowed to flush the higher elevated parts of the project area (Mitsch and Gosselink 2000; Edwards and Proffitt 2003) limiting the structure and function of the project area wetlands. It appears that the project area wetlands would have had greater structure and functions if the designated canals and shallow water bodies were filled evenly and the pre-existing barriers would have been altered to improve hydrology.

The last lesson is that the TE-23 project and reference area Gulf of Mexico shorelines are dynamic and highly erosional. Dredged materials have been placed on these beaches four times since project construction. For the three earliest events (1998, 2007, and 2012), considerable shoreline transgressions have removed material from the TE-23 shorelines through longshore or cross-shore (tropical and winter storms) transport mechanisms. On the later event (2015) no data has been collected to date. However, the current winter (2015-2016) has had strong southern winds and the beaches are displaying signs of transgression, so shoreline erosion is the likely outcome. During longshore and/or cross-shore events, sediments have been shown to be transported to the west and the north (Curole et al. 2015). Moreover, the Belle Pass Rock Jetties influence the shoreline transgressions in the TE-23 project and reference areas by reducing the littoral transport of sand to the western headland (Dantin et al. 1978; Penland and Suter 1988). As a result, natural re-nourishment of these beaches is insufficient to maintain a constructed shoreline position. It seems that the TE-23 project and reference area shorelines will continue to expand with sediment inputs and transgress in the absence of mineral additions.

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Appendix A
(Inspection Photographs)

Figure A-1. **View of rock along closure No. 5 near the western jetty at the mouth of Bell Pass.**

Figure A-2. **View of low rock along Closure No. 5.**

Figure A-3. **View of low rock at the end Closure No. 5.**

Figure A-4. **View of low rock at the end Closure No. 5.**

Figure A-5. View of typical rock height along Bell Pass.

Figure A-6. View of rock along mouth of southern inlet on west side of Bell Pass.

Figure A-7. View of filled in pipeline canal at back inlet.

Figure A-8. View of rocks at just before high elevation fill areas.

Figure A-9. View of rocks approaching Closure No. 4 from south side.

Figure A-10. View of the Closure No. 4 rock structure. Note the water flow over damaged segments of the closure.

Figure A-11. Northern rock limit along Bell Pass.

Figure A-12. Channel formed from severe marsh buggy tracks. The original tracks were created during TE-23 construction in 1998 and were shaped into a single and expanded channel over time.

Figure A-13. Northern edge of marsh fill area along Evans Canal.

Figure A-14. Damaged Closure No. 1 sheet pile wall used as containment during the 2007 maintenance event.

Figure A-15. View of the large breach in the Closure No. 1 sheet pile wall.

Figure A-16. View of the southern extent of the breached Closure No. 1 sheet pile wall.

Figure A-17. View of the northern extent of the breached Closure No. 1 sheet pile wall. Note batter piles were only placed across a quarter length segment of the closure structure.

Appendix B
(Three Year Budget Projection)

WEST BELLE PASS HEADLAND RESTORATION / TE23 / PPL2

Three-Year Operations & Maintenance Budgets 07/01/2016 - 06/30/2019

Project Manager	O & M Manager	Federal Sponsor	Prepared By
	Babin	USACE	Babin

	2016/2017	2017/2018	2018/2019
Maintenance Inspection		$ -	
Structure Operation	$ -	$ -	$ -
Administration	$ -	$ -	$ -
CPRA Administration	$ 20,000.00	$ -	$ -
Maintenance/Rehabilitation			

16/17 Description: Projected administration for project close-out

E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

17/18 Description

E&D	$ -
Construction	
Construction Oversight	
Sub Total - Maint. And Rehab.	$ -

18/19 Description:

E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

	2016/2017	2017/2018	2018/2019
Total O&M Budgets	$ 20,000.00	$ -	$ -

O&M Budget (3 yr Total)	**$ 20,000.00**
Unexpended O&M Funds	**$ 78,429.00**
Remaining O&M Budget (Final)	**$ 58,429.00**

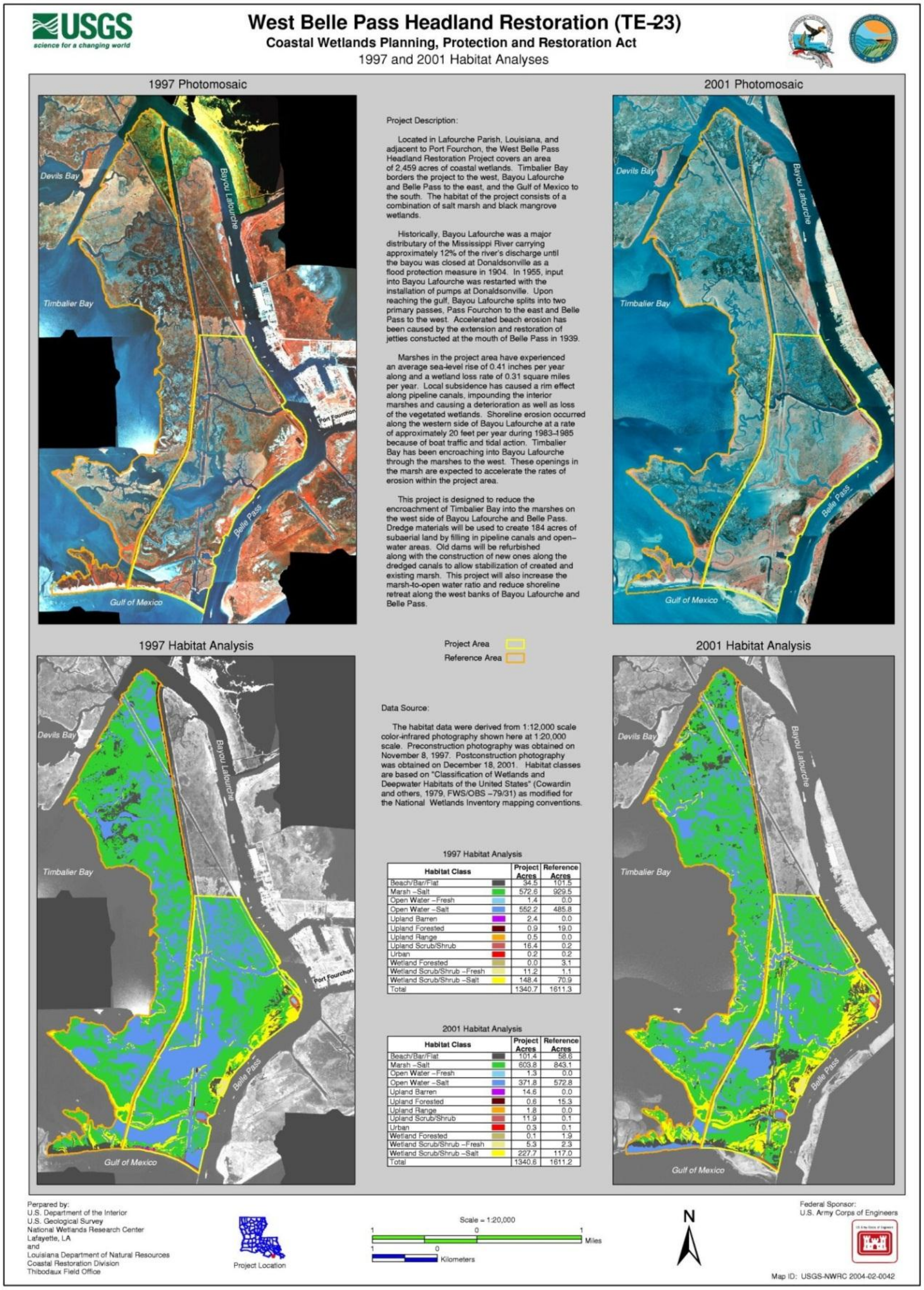
OPERATIONS & MAINTENANCE BUDGET WORKSHEET

Project: **TE-23 West Belle Pass Headland Restoration**

The 20 year project life is complete and the project is being closed out. No other maintenance will be performed on this project. Below are the final projected budget numbers for the project based on LaGov expenditures and the COE Lana Report:

Approved O&M Budget (Lana Report):	$ 448,211
Expenditures:	
2006 Repair of Sheetpile closure wall: *(USCOE performed this work)*	$-300,625
CPRA Total Expenditures:	$ -40,782
2016 Fund Transfer from O&M to Monitoring:	$ -28,375
Total Estimated Remaining Budget (Final):	**$ 78,429**

Appendix C
(TE-23 Land/Water and Habitat Analysis Maps)



Project Description:

Located in Lafourche Parish, Louisiana, and adjacent to Port Fourchon, the West Belle Pass Headland Restoration Project covers an area of 2,459 acres of coastal wetlands. Timbalier Bay borders the project to the west, Bayou Lafourche and Belle Pass to the east, and the Gulf of Mexico to the south. The habitat of the project consists of a combination of salt marsh and black mangrove wetlands.

Historically, Bayou Lafourche was a major distributary of the Mississippi River carrying approximately 12% of the river's discharge until the bayou was closed at Donaldsonville as a flood protection measure in 1904. In 1955, input into Bayou Lafourche was restarted with the installation of pumps at Donaldsonville. Upon reaching the gulf, Bayou Lafourche splits into two primary passes, Pass Fourchon to the east and Belle Pass to the west. Accelerated beach erosion has been caused by the extension and restoration of jetties constucted at the mouth of Belle Pass in 1939.

Marshes in the project area have experienced an average sea-level rise of 0.41 inches per year along and a wetland loss rate of 0.31 square miles per year. Local subsidence has caused a rim effect along pipeline canals, impounding the interior marshes and causing a deterioration as well as loss of the vegetated wetlands. Shoreline erosion occurred along the western side of Bayou Lafourche at a rate of approximately 20 feet per year during 1983-1985 because of boat traffic and tidal action. Timbalier Bay has been encroaching into Bayou Lafourche through the marshes to the west. These openings in the marsh are expected to accelerate the rates of erosion within the project area.

This project is designed to reduce the encroachment of Timbalier Bay into the marshes on the west side of Bayou Lafourche and Belle Pass. Dredge materials will be used to create 184 acres of subaerial land by filling in pipeline canals and open-water areas. Old dams will be refurbished along with the construction of new ones along the dredged canals to allow stabilization of created and existing marsh. This project will also increase the marsh-to-open water ratio and reduce shoreline retreat along the west banks of Bayou Lafourche and Belle Pass.

Data Source:

The habitat data were derived from 1:12,000 scale color-infrared photography shown here at 1:20,000 scale. Preconstruction photography was obtained on November 8, 1997. Postconstruction photography was obtained on December 18, 2001. Habitat classes are based on "Classification of Wetlands and Deepwater Habitats of the United States" (Cowardin and others, 1979, FWS/OBS -79/31) as modified for the National Wetlands Inventory mapping conventions.

1997 Habitat Analysis

Habitat Class	Project Acres	Reference Acres
Beach/Bar/Flat	34.5	101.5
Marsh -Salt	572.6	929.5
Open Water -Fresh	1.4	0.0
Open Water -Salt	552.2	485.8
Upland Barren	2.4	0.0
Upland Forested	0.9	19.0
Upland Range	0.5	0.0
Upland Scrub/Shrub	16.4	0.2
Urban	0.2	0.2
Wetland Forested	0.0	3.1
Wetland Scrub/Shrub -Fresh	11.2	1.1
Wetland Scrub/Shrub -Salt	148.4	70.9
Total	1340.7	1611.3

2001 Habitat Analysis

Habitat Class	Project Acres	Reference Acres
Beach/Bar/Flat	101.4	58.6
Marsh -Salt	603.8	843.1
Open Water -Fresh	1.3	0.0
Open Water -Salt	371.8	572.8
Upland Barren	14.6	0.0
Upland Forested	0.6	15.3
Upland Range	1.8	0.0
Upland Scrub/Shrub	11.9	0.1
Urban	0.3	0.1
Wetland Forested	0.1	1.9
Wetland Scrub/Shrub -Fresh	5.3	2.3
Wetland Scrub/Shrub -Salt	227.7	117.0
Total	1340.6	1611.2

Figure C-1. Pre- (1997) and post-construction (2001) photomosaics and habitat analysis of the West Belle Pass Headland Restoration (TE-23) project and reference areas.

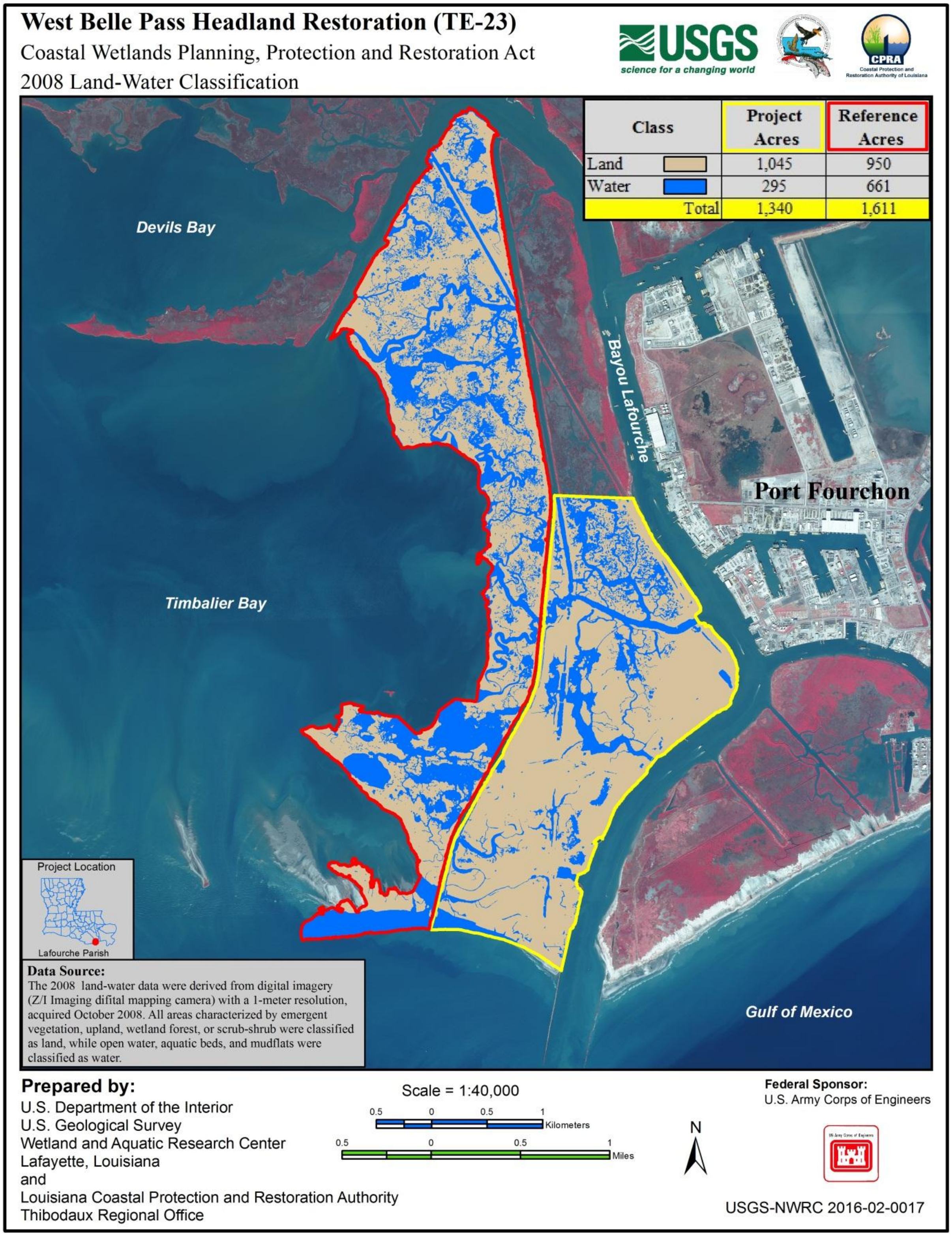


Figure C-2. Post-construction (2008) land/water analysis of the West Belle Pass Headland Restoration (TE-23) project and reference areas.

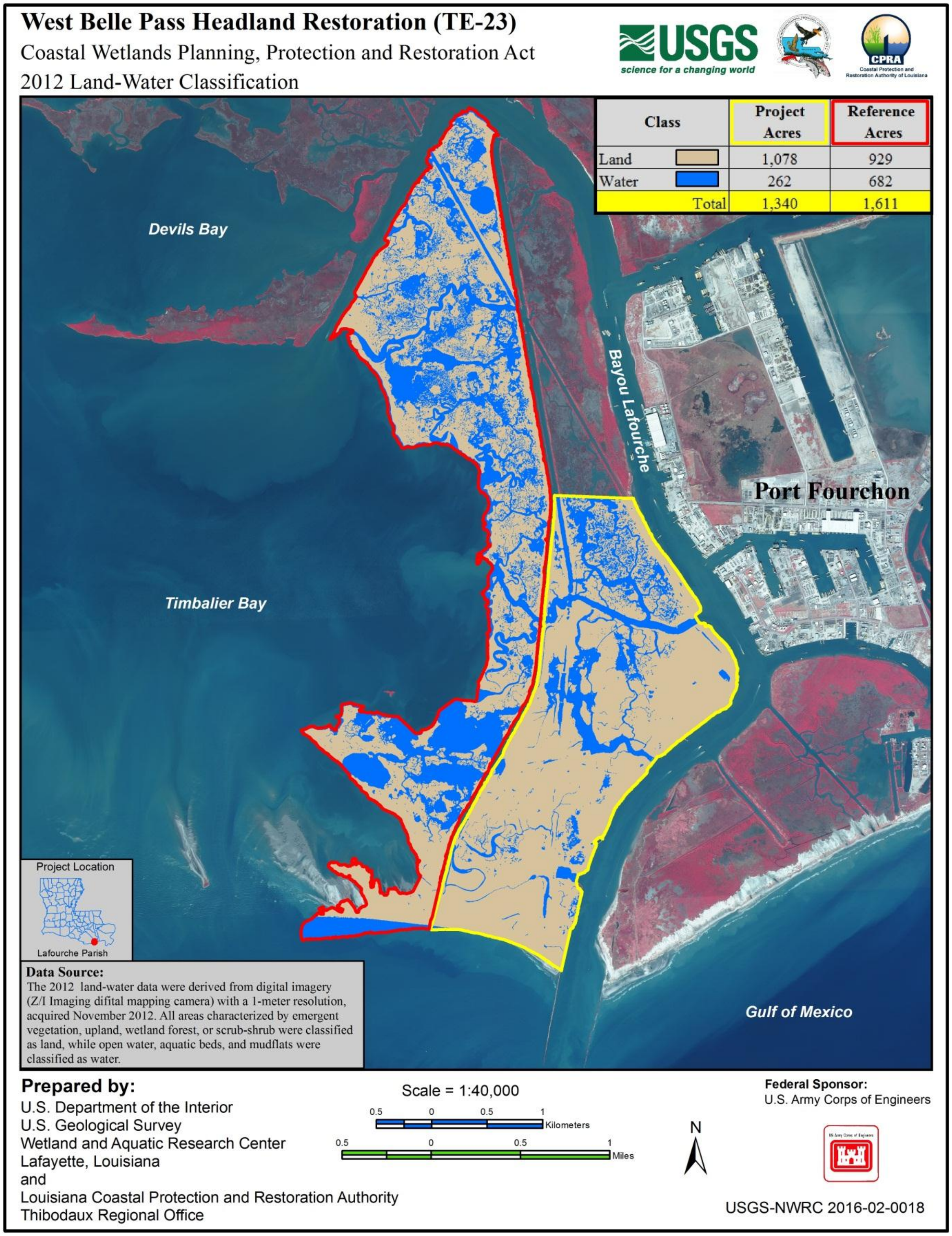


Figure C-3. **Post-construction (2012) land/water analysis of the West Belle Pass Headland Restoration (TE-23) project and reference areas.**

Appendix D
(TE-23 Shoreline Change Graphics)

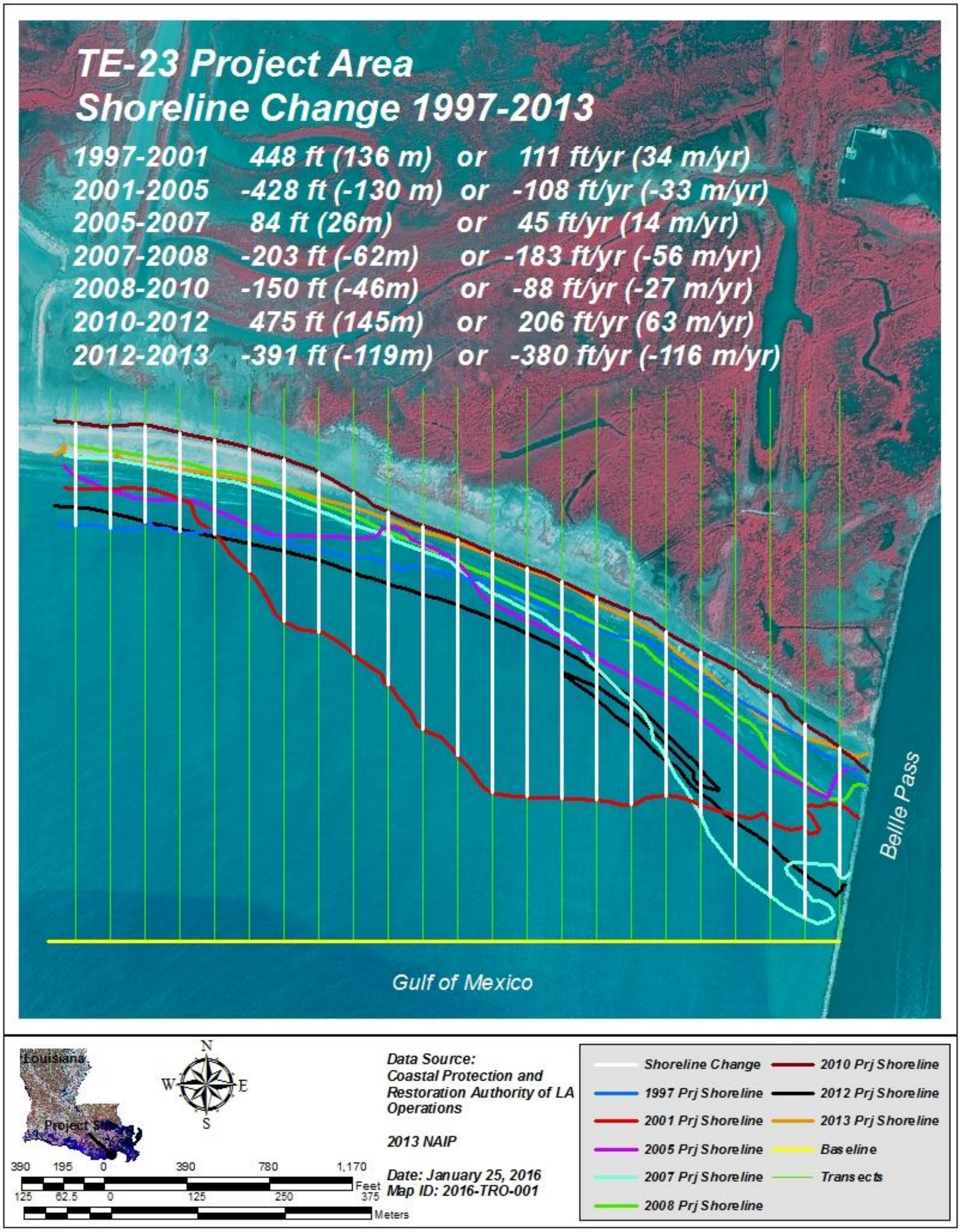


Figure D-1. **Post-construction shoreline change and position delineations along the West Belle Pass Headland Restoration (TE-23) project area's Gulf of Mexico shore in Nov 1997, Nov 2001, Nov 2005, Sep 2007, Oct 2008, Jul 2010, Nov 2012, and Nov 2013.**

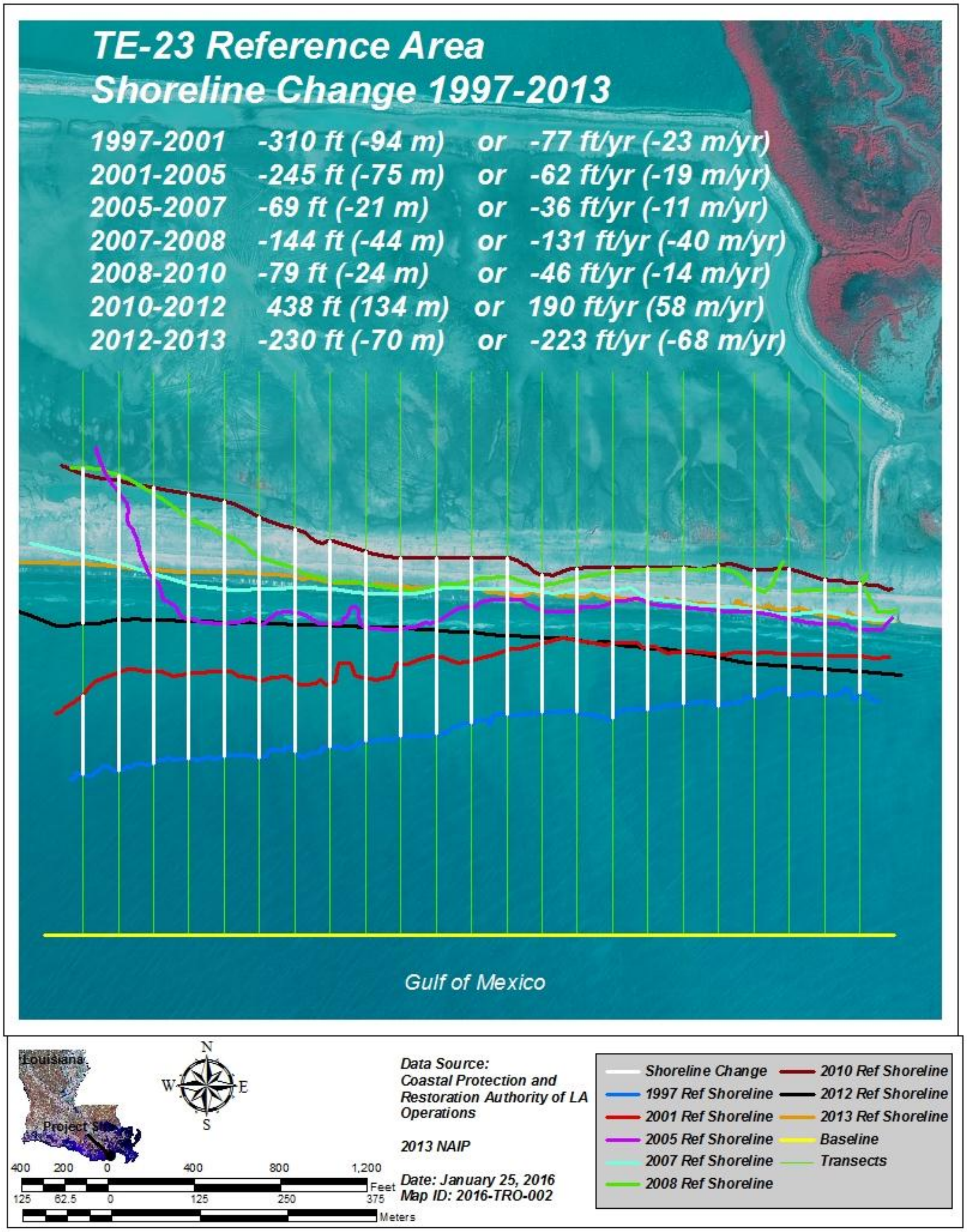


Figure D-2. **Post-construction shoreline change and position delineations along the West Belle Pass Headland Restoration (TE-23) reference area's Gulf of Mexico shore in Nov 1997, Nov 2001, Nov 2005, Sep 2007, Oct 2008, Jul 2010, Nov 2012, and Nov 2013.**